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PROGRESS REPORT

1936

FREMONT COUNTY BURNING PROJECT

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Supervision - Reports
Fremont County Burning Project

May 8, 1937

MEMORANDUM FOR DR. STEWART AND DIRECTOR BAILEY:

The accompanying progress report presents analyses and discussions in detail of the results of the Fremont County Burning Project.

Certain factual information concerning the use of fire in range management is extremely essential before fire can be safely recommended for use on any area but that upon which the study was conducted.

1. Effect of fire on other grass species similar in growth habit to Poa spp. and Festuca idahoensis as well as the effect of fire on palatable weed species. As shown by the results of the study severe decreases occur in Poa spp. and Festuca as result of burning. If this same result is found to apply to other important forage species the use of fire must be restricted to areas where very little of the species subject to damage occurs.
2. The effect of climate and the occurrence of sagebrush seed years on the success of burning. Since the initiation of the Fremont County study no years of abundant seed production of sagebrush have occurred. The success of burning may be materially decreased if an abundant seed supply is present immediately after the burn.

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3. A complete investigation into the effect of fire on soil properties and the duration of such effects. A preliminary study reported in the 1936 Progress Report, U. S. Sheep Experiment Station presents evidence contrary to the common belief that fire inflicts injury to soil properties. This should be further investigated.

4. Possibility of removal of sagebrush by fire followed by re-seeding on areas where little or no herbaceous understory exists. Fully 50 percent of the spring-fall range in Idaho is in a condition such that reseeding will be necessary if burning is resorted to in removing sagebrush.

5. Determination of the most profitable management of burned areas following burning arriving at the perpetuation of the grass species and the prevention of return of a heavy cover of sagebrush.

This last phase is probably the most important of the group in that the permanency of the benefits derived from burning is dependent upon management subsequent to the fire. An investigation of this phase was incorporated in the Fremont County Burning Project but certain features of the design, and subsequent records have almost completely invalidated any results that might be secured. The status of this study is briefly presented in the accompanying table.

Table 1.- History of plots used in study of proper management of burned ranges.

AREA	Year of burn	Intensity of burn	Treatment prescribed	Grazing record 1934	1935	1936
Enclosure 1	Unburned	-	Unburned - ungrazed	-	-	-
" 2	Partially 1933	Heavy	Unburned - ungrazed	-	-	-
" 3	1932	Medium	Burned - ungrazed	-	-	-
" 4	1933	Heavy	Burned - ungrazed	-	-	-
" 5	Unburned[2/]	-	Unburned - ungrazed	-	-	-
Grazed Plot 1	Unburned	-	Unburned - grazed	1 - 5%		
" " 2	Unburned	-	Unburned - grazed	1 - 5%		
" " 3	1932	Medium to light	Burned - protected 2 springs and 1 fall	10 - 20%	No records[1/]	No records
" " 4	1933	Heavy	Burned - protected 1 spring and 1 fall	0		
" " 5	1934	Light	Burned - unprotected	-		
" " 6[3/]	1932 and 1934	Light	Burned - protected 1 spring	-		

1/ From observation during the years of no record, utilization was not any heavier if as heavy as during 1934.

2/ Established in 1934, the remainder of the series were established in 1932.

3/ This plot never used because of double burn.

A brief perusal of this table immediately reveals the danger of drawing conclusions from these plots for the following reasons:

1. A reasonable experimental design demands that all plots be subject to the same conditions except for the treatments applied. This is not the case, transects were burned in 1932 and 1933, enclosure 3 and grazed plot 3 in 1932, enclosure 4 and grazed plot 4 in 1933 and grazed plot 5 in 1934.
2. Grazing records are lacking as to the actual treatment received. A certain definite plan was laid out for these areas but they were merely exposed to grazing, no assurance is given that they received the designated treatment. In reality from observation it is definitely true that many of the areas exposed to grazing did not receive any use at all.
3. The experimental design does not permit a valid test of the treatments. As pointed out in the last of the report with but few exceptions no replications of treatment are provided for. Significance of treatments must therefore be tested in terms of error within blocks instead of error between blocks. As shown by the analysis of variance to test the significance of the difference between grazed-unburned treatment and burned-ungrazed treatment the difference between plots receiving the same treatment is significant and when treatments are tested in terms of error between blocks no significant treatment effect can be found.

4. Difference between burn intensity. Neither are the individual 1-acre plots of the same burn intensity. As shown in the manuscript by Pickford difference between burn intensities as affecting grass densities are frequently significant. Thus part of the differences between plots attributed to treatment may be due to differences in intensity of burn.

Since the initial design and subsequent procedure in conducting the experiment to determine the best method of management following burning is such that actual treatment does not follow prescribed treatment and no test of the significance of treatments can possibly be made, the following recommendations, subject to your approval, are made for the conduct of future studies of burning.

1. Work at the Fremont County Burning area should be limited to (a) a periodic check of transect plots at 4-year intervals (b) maintenance of enclosure fences for purely demonstrational purposes (c) discontinuance of management studies on one-acre plots.
2. All work pertaining to management of burned areas should be confined to the U. S. Sheep Station experimental range as outlined in Subproject 4, U.S.S.E.S. Plan of Work.
3. A definite organized program in cooperation with the reseeding project should be begun to determine the feasability of reseeding on burned-over areas.

4. An examination of other burned areas within the eastern portion of the Snake River plains should be conducted to determine the limitations of fire for use in management of spring-fall ranges.

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4/24/37

PROGRESS REPORT

FREMONT COUNTY BURNING PROJECT

Table of Contents

Summary and recommendations.

Effect of controlled burning on spring-fall range in southeastern Idaho (manuscript covering period 1932 to 1934, inclusive).

Supplement covering results during period 1935 and 1936.

Grazing management following burning.

Summary

The following summary and conclusions are for the entire period of the experiment 1932 to 1936, inclusive.

Effects of burning

Climate during the period has exacted a toll of 55 percent in total density on unburned areas. Grasses cover 80 percent, weeds 60 percent and shrubs 30 percent less area than they did in 1932.

On burned areas using all burn classes summarized as a group climate plus burning have reduced the total density 78 percent, grass density 75 percent, weeds 30 percent, and shrubs 93 percent.

Thus, subtracting the effects of climate alone as indicated by the unburned areas total density has been decreased 23 percent, grasses increased 5 percent, weeds increased 30 percent and shrubs decreased 63 percent. It is the decrease in shrubs then that is responsible for the decrease in total density.

Grasses by species exhibit markedly different reactions to burning. *Agropyron dasystachyum* has been nearly doubled and *Stipa* spp. have essentially maintained themselves. *Festuca idahoensis* has nearly disappeared and *Poa* spp. have decreased markedly. This means an increase by a species of lesser palatability with decreases in the two more palatable species of grasses.

Volume herbage production on burned and unburned areas shows more clearly the effect of burning.

Availability of herbage has been increased from 52 percent on unburned areas to 97 percent on heavily burned areas.

The increase in grass and weed herbage following burning nearly offset decreases caused by removal of the sagebrush herbage.

In terms of available herbage increases have been 34 percent on the light, 69 percent on the medium and 28 percent on the heavy burns. Increases in grass production of from 75 to 125 percent are responsible for changes in total production.

As with density Festuca idahoensis and Poa spp. decrease with intensity of burn, Stipa spp. increase on light and medium intensity burns but decrease on heavy burns. Agropyron dasystachyum doubles or triples on all burns.

"All weed" production has doubled or tripled in all burn classes.

Increases in palatable herbage were slightly different than that of all herbage due to the increase in less palatable species and decreases in palatable species. Despite this forage has doubled on light and heavy burn intensities and tripled on medium burn intensities.

Basal area follows the same trends as those indicated by density.

Leaf height of grasses was decreased, flower stalks were increased by burning.

Burns of heavy intensity caused significant decreases in organic matter and amount of total nitrogen in the top half inch of soil. Light and moderate burns showed no significant effect on soils.

Wind erosion occurring immediately subsequent to burning and largely arrested upon reestablishment of the plant cover, increased directly with the intensity of burn.

Percent of soil moisture was uniformly slightly decreased on burned areas.

From the foregoing it is concluded that on similar range areas, controlled burning of spring-fall range with fire will effectively remove sagebrush without apparent detriment to the soil or remainder of vegetation.

Grazing management after burning

One spring seasons and one spring and one fall seasons protection after burning tend to be the most favorable to the return and establishment of the grass and herbaceous vegetation.

No protection after burning tends to work ahardship on the vegetation.

A longer protection period than one spring and one fall season's protection is not detrimental to reestablishment of vegetative cover.

Since no records of grazing use were taken, reliance cannot be placed on the preceding statement because the areas may not have been grazed even though they were exposed to grazing.

Recommendations

In view of the facts that (1) results from this experiment are only applicable to similar sites under similar conditions (2) damage occured to palatable grass species and (3) proper grazing management has not been concretely defined the following phases of burning must be investigated before the practice can be widely recommended:

1. A more complete investigation into the effect of fire on soils and the duration of any such effects.

2. The effect of climate and sagebrush seed years on the success of burning.
3. The most profitable management of burned areas aimed at the perpetuation of the grass species and the prevention of return of a heavy cover of sagebrush.
4. Effect of fire on other grass species similar in growth habit to Poa spp. and Festuca idahoensis. Effect of fire on palatable weed species.
5. Possibility of removal of sagebrush by fire followed by reseeding on areas where little or no understory exists.

EFFECT OF CONTROLLED BURNING ON SPRING-FALL RANGE IN SOUTHEASTERN IDAHO

Sagebrush (Artemisia tridentata) is now the most abundant plant on ranges used for spring-fall grazing in the Intermountain region. These ranges comprised of foothills and plains, lying at elevations between the mountainous summer range and the lower, more arid winter range, have been highly in demand for more than 50 years. With no widespread attempt to regulate grazing until recently, these ranges have long been overgrazed resulting in an average loss of 65 percent of their original grazing capacity.[1/]

Observations by Clements (4) and recent investigations[1/] indicate that sagebrush is not a true dominant on spring-fall range except on the more arid sites. It has greatly increased in the more favorable situations as the palatable grasses, weeds and shrubs have become weakened by overgrazing. Since sagebrush furnishes little forage for livestock, competes critically with better forage plants for soil moisture and, because of its dense, woody growth, makes a considerable amount of valuable herbaceous forage unavailable to grazing animals, its presence in excessive amounts on spring-fall range is undesirable.

1/ Stewart, George; Pickford, G.D.; and Hutchings, S. S. Influence of past grazing practices on present forage conditions on the open spring-fall and winter ranges of the Intermountain region. (Unpublished mss. copy on file U.S.D.A., Forest Service, Washington, D. C.)

If the grazing capacity of depleted spring-fall range is to be built up the better forage plants must be allowed to partially or completely replace sagebrush. Since sagebrush holds its place tenaciously when once established on spring-fall range, rehabilitation by allowing better forage species to increase through natural revegetation is necessarily a slow process. On the more arid sites where sagebrush is unquestionably dominant, careful range management, which will allow the better forage plants to increase and to replace sagebrush to a certain extent is perhaps the only solution, supplemented on the most heavily depleted areas with artificial reseeding of some aggressive forage species.

Where the shrub is not a true dominant artifical removal on sites which support the original highly palatable grasses and other forage species in sufficient amounts to increase rapidly once released from suppression, offers a possibility of speeding up the process provided the method is not equally harmful to better forage species.

Removal of sagebrush by burning is perhaps the quickest and most economical artificial method since the shrub is highly inflammable during the period of subdormancy in late summer when herbaceous vegetation is cured. Unfortunately, unwise use of fire on sagebrush range together with unregulated grazing has resulted in serious deterioration of better forage species, Pickford (13), so that conservative range users and administrators have come to regard any use of fire as harmful.

The aim of the present study is to determine the effect of controlled burning in conjunction with regulated grazing on the vegetation and soil of spring-fall range where sagebrush is not truly dominant. This study begun in 1932 is being conducted by the Intermountain Forest and Range Experiment Station in cooperation with the state of Idaho and the Fremont County Woolgrowers Association. This paper is concerned with the immediate effects of controlled burning in the absence of grazing.

No previous experimental work has been done in the Intermountain region to ascertain the practicability of controlled burning to improve such ranges. One experiment on sagebrush range in Colorado by Hansen (7) reports favorable results from burning. Results from other investigators, Ademson (1), Aldous (2) (3), Greene (6), Hensel (8) and Liebenberg (10), working in the tall grass prairie of eastern Kansas, in the longleaf pine region of southern Mississippi and in grazing regions in foreign countries give interesting information on the use of fire in range management. However, due to widely different conditions, these results cannot be applied directly to the problem in the Intermountain region.

An area approximately 2 miles square, located 15 miles north of St. Anthony, Idaho on the northeastern edge of the Snake River plains was selected for study. The topography, as described by Russell (15), is a lava plain with no drainage features, the only relief being numerous volcanic cones and low broad elevations formed of lava which

project like islands above an otherwise flat or gently rolling terrain. The soil, of basaltic origin mixed with a yellowish-white, silt-like aeolian deposit, differs from typical Snake River plains soils in that blow sand, probably from the same source as nearby traveling dunes, has settled over the area resulting in a fine sandy top soil with a basaltic clay subsoil. The soil depth varies from zero on lava outcrops to 3 feet and more on the plain.

The climate is typically continental. Climatic records at Ashton, about 10 miles east of the area and similar in elevation, show a normal annual precipitation of 15.85 inches for the 38-year period, 1897-1934. The normal precipitation is rather evenly distributed between winter and summer, although precipitation varies greatly from year to year and from month to month with alternating periods of drought and excess. Practically all winter precipitation is snow unevenly distributed by drifting. Summer precipitation comes in the form of showers, largely local in extent. The prevailing wind, except in the winter months when cold north winds are common, is from the southwest. From May until November, strong southwesterly winds occur almost daily, rising about noon and subsiding at sunset. These winds are dry and frequently hot, causing a high evaporation loss from soil and vegetation. The daily range between maximum and minimum temperatures is great at all times of the year. Summer temperatures may reach a maximum of 100° F. or more while winter temperatures have been recorded at Ashton as low as -35° F. The length of frost-free period is approximately 96 days.

The vegetation is monotonously uniform. Except on the lava rock "islands" where bluebunch wheatgrass (Agropyron spicatum), matchweed (Gutierrezia sarothrae), cactus (Opuntia spp.), false yarrow (Chaenactis douglasii) and other rock-loving species occur, the landscape is everywhere dominated by sagebrush, growing in an unbroken stand two to three feet in height. Associated with the sagebrush are such shrubs as bitterbrush (Purshia tridentata), Oregon grape (Odostemon repens), snowberry (Symphoricarpos oreophilus), rabbitbrush (Chrysothamnus spp.) and rose (Rosa spp.). A small amount of fineleafed sage (Artemisia tripartita) is present. Despite the dense stand of sagebrush, there is a good understory of herbaceous vegetation, of which grasses and grass-like plants are most important. These include thickspike wheatgrass (Agropyron dasystachyum), needlegrasses (Stipa spp.), bluegrasses (Poa spp.), sedge (Carex spp.), junegrass (Koeleria cristata) and Idaho fescue (Festuca idahoensis). Weeds are unimportant as a whole, although pussytoes (Antennaria spp.), everlasting (Eriogonum spp.), aster (Aster spp.), goldenrod (Solidago missouriensis), geranium (Geranium viscosissimum), and mountain sunflower (Helianthella uniflora) are of general occurrence. The vegetation is composed of approximately 45 percent grasses, 45 percent shrubs and 10 percent weeds. Sagebrush alone represents almost 40 percent of the vegetation.

According to well-founded information, the area was accidentally burned over in the exceptionally dry summer of 1910. Sagebrush was largely exterminated and grass grew abundantly subsequent to the burn.

Scientific range management was not practiced after the burn, however, and after about 10 years sagebrush began to increase noticeably, until in 1932 the brush was so dense as to make handling sheep on the area difficult. There still remained, however, a considerable understory of valuable grasses and weeds.

The area is not considered typical of the Snake River plains in their entirety. Proximity to the Snake River and to the Snake River mountains places it in a storm path with more than average precipitation. Presence of sand in considerable amounts in the top soil also aids in conserving soil moisture. It is, however, an area where sagebrush is not considered a true dominant and as such, offers an excellent opportunity to test the practicability of sagebrush removal by controlled burning.

Four parallel transects, each 10,000 feet long, were established in 1932. These transects, spaced at half-mile intervals from north to south, bear approximately west from the east side of the area, crossing the path of the prevailing winds. One hundred estimation stations permanently located with iron pegs were established on each transect at intervals of 100 feet. Eight meter-square quadrats and eight browse plots, 4 feet by 25 feet, were permanently established at mechanical intervals along each transect. Browse plots and quadrats were alternated at intervals of 600 feet, each plot being 25 feet west of a station, with the exception that the quadrats were placed on line in the meter-square opening closest to the 25-foot measurement to avoid heavy brush and lava outcrops.

In addition to the four transects, eleven 1-acre plots, four of which were to be left unburned, were established throughout the area to serve as future checks on the effect of grazing on burned range. Six 33-foot-square major plots were also established within the experimental tract to supplement the 1-acre plots. Ten permanent estimation stations were mechanically located within each acre plot and four within each major plot. Two meter-square quadrats and two 4 by 25-foot browse plots were located at random within each of the four outside 1-acre plots and in two of the plots located inside the experimental tract. Four quadrats and four browse plots were established in each of the remaining four 1-acre plots.

Initial vegetation and soil data were collected in August and September of 1932. Lava outcrops were mapped within all 1-acre plots and on a strip 100 by 10,000 feet on each transect. Vegetation on the deeper soils was so uniform that it was considered one vegetative type, classified as sagebrush-grass. The basal area of all vegetation on each quadrat was mapped with the Hill pantograph, Hill (9). The average height of all shrubs growing on each of the browse plots was recorded and their crown spreads were mapped by the coordinate method described by Pickford and Stewart (14). The density of current aerial growth for all species which produced quantities of one-half square foot or more within a circle 100 square feet in area around each permanent estimation station was recorded and all species occurring on the plot were listed. All plot estimations were classified as "lava" or "sagebrush-grass" depending on the type in which the stake was located.

Soil samples were drawn at 12 randomly located points in the sagebrush-grass type along each transect. Two composite samples, one consisting of three individual collections of the top half inch of litter and soil, and the second consisting of three collections of the 2½-inch layer of soil immediately below, were taken at each station, making 96 samples in all. Standard laboratory analyses were made of these samples to determine (1) the amount of organic matter present; (2) the amount of gravel, sand, silt, and clay; (3) total nitrogen present; (4) water-holding capacity; (5) moisture equivalent; and (6) pH. The concentration of hydrogen ion was determined by the Hellige disc comparator method.

METHODS

No grazing was permitted on the area during 1932 or 1933, thus allowing grasses to produce a maximum aerial growth providing an ample supply of inflammable material to carry the fire. The area was burned over in August and September of 1933 after grasses and other herbaceous forage had cured. No artificial methods, such as sprinkling with oil, spreading straw, or other means of increasing natural fuel supply and combustibility were used preparatory to burning. The result was a normal sagebrush burn, made even more typical by the adequate size of the experimental area.

No grazing was permitted during the season of 1934, thus affording an opportunity to measure the effect of burning on the soil and vegetation with the factor of grazing eliminated. The vegetation at all

estimation stations was again estimated in July and August 1934, one year after burning. The plot estimates were classified both as to vegetative type and as to intensity of burn. Four different intensities of burn were recognized, namely: (1) unburned; (2) light burn; (3) moderate burn; and (4) heavy burn. Classification was made on the following basis: (1) heavy burn -- all branches of sagebrush destroyed, leaving only the larger trunk or bole; (2) moderate burn -- larger branches of sagebrush remaining, but smaller branches and twigs consumed; (3) light burn -- smaller branches and twigs remaining on bush, plants completely or partially killed. Intensity of burn was mapped on all 1-acre plots and on a 100 by 10,000-foot strip along each transect. Supplemental notes on wind erosion were taken on all sample plots. On all quadrats the vegetation was recharted, the intensity of burn was noted, and estimates were made of plant vigor and degree of wind erosion. Crown spread of surviving shrubs was remapped on all browse plots. Random measurements were made on three important grass species in comparable sites on unburned range, range burned lightly and moderately in 1932 and range burned moderately and heavily in 1933, taking into consideration number of flower stalks, average and maximum flower stalk length and average and maximum leaf length. Data were taken on regeneration of browse species by counting the occurrence of live and dead plants encountered on random lines through 1933 burn. Soil samples were gathered at the same stations and by the same methods as in 1932 and were analyzed similarly.

RESULTS

The 400 transect estimation plots were considered sufficient to give a random sample of the vegetation of the area. Data from the estimation stations within the 1-acre and major plots are, therefore, omitted in this presentation. Data from all quadrats and browse plots are included in order to obtain a sample large enough to be considered representative.

The present study is concerned only with the sagebrush-grass type. Lava rock outcrops, which constitute the so-called lava type, are sparsely vegetated and of little value for grazing. Three hundred of the randomly distributed estimation plots, 58 quadrats, 48 browse plots and 48 soil sampling stations occurred in the sagebrush-grass type. Four browse plots which were only partially burned are eliminated from this discussion.

The following summarizes the treatment of the various plots:

	NUMBER			
	Unburned	Light Burn	Moderate Burn	Heavy Burn	Total
Transect estimation plots	117	43	72	68	300
Quadrats	20	15	12	11	58
Browse plots	15	12	5	12	44
Soil sampling stations	17	8	7	16	48

Effect of climate on vegetation and soil

In semi-arid regions, of which the experimental area is typical, the amount and seasonal distribution of precipitation is probably the most important climatic factor influencing growth and behavior of vegetation. The period 1932 to 1934 began with an extremely favorable year followed by one of nearly average precipitation and was culminated by a year of serious drought. Precipitation data from Ashton, 10 miles east of the experimental area, for the period 1932 to 1934 are summarized below. Precipitation on the area is thought to have been fairly comparable.

Year	PRECIPITATION (Inches)	
	Annual (Aug. to July, incl.)	Seasonal (Oct. to June, incl.)
Normal	15.85	13.05
1932	23.77	18.14
1933	14.70	13.32
1934	11.51	9.42

Since growth of forage plants on the experimental area is largely confined to the period April to July inclusive, any precipitation occurring after approximately August 1 is of little importance to the current growth. It is, however, important to plant growth since it tends to build up soil moisture supplies which are stored over winter and used by the plants in the following year. Basing the precipitation year on the period from August 1 of the preceding year to July 31 of the current year, therefore, gives data which are readily correlated with the responses of vegetation to climate. Precipitation during the period July 1 to September

30, however, is largely ineffective due to the prevalence of low humidities and hot dry winds. Precipitation occurring from October 1 to June 30 is therefore considered to have the greatest effect on the vegetation.

Normal precipitation at Ashton for the October to June period based on a 38-year record is 13.05 inches. Precipitation in 1932 was 28 percent above normal while in 1934 it was the same amount below and was only 53 percent of 1932. Temperatures several degrees higher than normal throughout the winter and spring of 1933-1934, together with a scarcity of snow accumulation caused plants to begin growth in March and likewise to mature by early June. Since the 3.48 inches of rainfall that fell during June, 1934 were subsequent to plant maturity the seasonal precipitation was actually only 46 percent of normal and only 33 percent of 1932. Precipitation in 1933 while subnormal when considered on an annual basis was slightly above normal for the period October to June.

The effect of this great variation in precipitation on the vegetation and soil of the experimental area is portrayed by the differences between 1932 and 1934 measurements on the various unburned plots. There was little reaction in soil properties to the climate of the 3-year period. Analysis of 1932 and 1934 soil samples collected at the 17 soil sampling stations on unburned range failed to show any material changes in pH, mechanical properties, amount of organic material, amount of total nitrogen present, or moisture equivalent. (Tables 8 and 9). There was, however, a marked vegetative response to the abnormal climatic conditions.

The volume of current aerial growth as well as its density is reflected in plant density estimates, thereby giving a relative volumetric measurement of annual fluctuations in plant growth. Density estimates of total plant cover on the 117 unburned plots averaged 65.1 percent less in 1934 than in 1932 (table 1). This reduction of current growth was most uniform and more severe in the grasses, where an average decrease of 77 percent ranging from 64.5 percent for the needlegrasses to 94.1 percent for the bluegrasses was evident. Thickspike wheatgrass, most abundant in 1932, became secondary to needlegrasses in 1934. The reaction of weeds to drought was erratic. Some annuals, such as plume weed (Adenostegia ramosa) which were present in 1932 were completely absent in 1934, while some perennials notably the asters, everlastings, geranium, mountain sunflower and goldenrod increased or maintained their 1932 densities. The density of weeds as a class decreased 52 percent from 1932 to 1934. Shrubs, usually considered more stable than either grasses or weeds, produced 56 percent less growth in 1934 than in 1932. This loss was confined chiefly to sagebrush and to bitterbrush. Rabbitbrush and Oregon grape both increased in density despite the influence of climate. Based on the most reliable species palatability data available, the 1934 forage value of the range represented by these plots was only 27.2 percent of the 1932 figure.

Effects of the 1934 drought on the basal area of grasses and on the crown spread of shrubs, both of which are less affected by climate than current foliage and shoot production, were measured on the 20 quadrats and 15 browse plots which remained unburned throughout the experiment. Total grass basal area [2/] showed a slight increase in 1934. This increase, however, was statistically insignificant (tables 3 and 4). No significant changes were evident for species which were general enough in occurrence to be treated statistically. All except bluegrasses, however, evidenced slightly decreased basal areas. Numbers of grass plants increased significantly. There were 78 more grass plants per quadrat in 1934 than in 1932 (table 5). Thickspike wheatgrass produced 46 more individual plants per quadrat than in 1932, a highly significant increase accounting for 60 percent of the total increase in numbers of grass plants. Other species showed small increases which were statistically insignificant. The general increase in grass individuals, with the exception of thickspike wheatgrass, probably was due to the breaking up of old clumps into smaller ones more than to the establishment of new plants, since the total basal area remained unchanged. In the case of wheatgrass, however, which grows from underground rootstocks in single shoots or in small tufts, establishment of new individuals was probably the case, accompanied by a shrinkage in size or disappearance of old tufts.

2/ Perimeter of individual grass clumps 1 inch or less above root crown.

Contrary to the trend of density estimates which measure only current leaf and shoot growth, the charted crown spread of sagebrush and bitterbrush was larger in 1934 than in 1932, indicating a greater area of potential foliage production (table 7). Bitterbrush, which is palatable to livestock, increased more than did the unpalatable sagebrush, indicating that protection from grazing may have given an impetus to its growth during the favorable years of 1932 and 1933. The average height of both species decreased in 1934 principally because current shoot growth and flower stalk production was at a minimum. Bitterbrush seedlings were completely absent in 1934 while sagebrush seedlings although greatly decreased from the 1932 amount still persisted. A few plants each of rabbitbrush, snowberry, prickly gilia (Leptodactylon pungens) and Oregon grape became established prior to the 1934 charting but crown spread of these species totalled less than 1 percent of the combined sagebrush and bitter brush crown spread.

Effect of controlled burning

The effect of controlled burning on vegetation and soil plus the added influence of climate is expressed by comparative differences between 1932 and 1934 measurements on the various burned plots. Effects of different intensities of burning on plant densities are shown in table 1. Due to the overwhelming effect of climate, densities were consistently less in 1934 than in 1932. The influence of different intensities of burning, however, is apparent over and above density changes due to drought.

Density of total plant cover showed for the burned plots a greater decrease from 1932 measurements than did the unburned series, the percent of decrease being in direct proportion to intensity of burn. This loss, primarily was due to the destruction of shrubs, especially sagebrush, by fire. While shrubs lost 56 percent of their 1932 density because of drought, this was increased to 92 percent by light burning and to 97 percent by burns of moderate and heavy intensities. All shrub species with the possible exception of rabbitbrush were injured by fire, sagebrush apparently being most susceptible. Sagebrush was virtually exterminated by burns of light and moderate intensities and completely disappeared in the heavily burned series. Bitterbrush, next to sagebrush in abundance in the shrub class lost density proportionately when subjected to the same intensities of burn. It was not, however, completely exterminated even in burns of heavy intensity, nor was any other shrub except sagebrush which alone seems to be incapable of sprouting from the roots after the crowns have been killed by fire.

Contrary to the trend of shrubs, the average density of grasses and weeds tended to be relatively higher on burns of all intensities than on the unburned series. While grasses as a class showed a decrease of 77 percent from 1932 densities on the unburned plots, differences between 1932 and 1934 measurements lessened as the intensity of burn increased, indicating a general acceleration of growth from burning. This trend was true of thickspike wheatgrass which showed reduction of density losses from 82 percent on unburned plots to 62 percent on the heavily

burned series. Bluegrasses and junegrass reacted similarly to wheatgrass although burns of heavy intensity appeared less stimulating than moderate burning to bluegrasses. Needlegrasses, sedges and Idaho fescue apparently were injured by fire. Idaho fescue, a highly palatable grass, which occurred in limited amounts on the area, lost 78 percent of its 1932 density due to drought which was increased to more than 90 percent on lightly and moderately burned plots. On the heavily burned series, fescue completely disappeared. Needlegrasses, next to wheatgrass in order of abundance on the area, showed a loss of approximately 10 percent more of their 1932 density on burned plots than on the unburned series. Intensity of burn, however, appeared unimportant as the density loss for each intensity remained practically unchanged. Sedges, which are considered with grasses in this paper, showed reduced densities, over and above that due to the influence of climate, in direct proportion to intensity of burn.

With the exception of plume weed, an annual which failed to grow in 1934 as the result of drought, and two perennials of shrubby character (pussytoes and everlasting), weeds were more abundant on the burned series in 1934. Weeds as a class lost 52 percent of their 1932 density on unburned plots while on light, moderate and heavy burns the loss was only 16 percent, 28 percent and 20 percent respectively. Asters, geranium, mountain sunflower and golden rod all increased noticeably in density on burned plots as compared with the unburned series, in some instances showing an increase over their 1932 densities, completely overcoming the effect of climate.

Table 1. Changes in average density of vegetation on estimation plots according to method of treatment.

	Density of Vegetation (1.00 equals complete cover)											
	Unburned 117 Plots			Lightly Burned 43 Plots			Moderately burned 72 Plots			Heavily Burned 68 Plots		
	1932	1934	% loss	1932	1934	% loss	1932	1934	% loss	1932	1934	% loss
Total density	.281	.098	65.1	.302	.065	78.5	.325	.062	80.9	.280	.051	81.8
Agropyron dasystachyum	.044	.008	81.8	.065	.018	72.3	.059	.021	64.4	.061	.023	62.3
Carex (grouped)	.021	.006	71.4	.009	.002	77.8	.014	.003	78.6	.013	.002	84.6
Festuca idahoensis	.009	.002	77.8	.002	T	95.5	.001	T	92.3	T	-	100.0
Koeleria cristata	.003	T	82.1	.004	.002	50.0	.004	.002	50.0	.002	.002	0.0
Poas (grouped)	.017	.001	94.1	.019	.002	89.5	.020	.003	85.0	.018	.002	88.9
Stipas (grouped)	.031	.011	64.5	.052	.013	75.0	.062	.015	75.8	.020	.005	75.0
Misc. Grasses	.001	.001	0.0	--	.002		T	T	0.0	T	T	+50.0
Total Grasses	.126	.029	77.0	.151	.039	74.2	.160	.044	72.5	.114	.034	70.2
Adenostegia ramosa	.006	--	100.0	.003	--	100.0	.005	--	100.0	.007	--	100.0
Antennaria microphylla	.014	.007	50.0	.009	.004	55.6	.008	.002	75.0	.005	T	98.1
Asters (grouped)	T	T	+150.0	.001	.004	+300.0	.001	.001	0.0	T	.001	+100.0
Eriogonums (grouped)	.002	.002	0.0	.002	.001	50.0	.002	.001	50.0	.001	T	81.8
Geranium viscosissimum	T	T	0.0	.001	.002	+100.0	.001	.002	+100.0	T	.001	+180.0
Helianthella uniflora	--	T		T	.001	+60.0	T	.001	+233.3	T	T	+100.0
Solidago spp.	T	.001	+100.0	.002	.002	0.0	.001	.002	+100.0	T	.001	+900.0
Misc. Weeds	.003	.002	33.3	.001	.002	+100.0	T	.004	+385.7	.002	.009	+350.0
Total Weeds	.025	.012	52.0	.019	.016	15.8	.018	.013	27.8	.015	.012	20.0
Artemisia tridentata	.110	.043	60.9	.093	.005	94.6	.107	.001	99.1	.116	--	100.0
Ceanothus spp.	.001	T	33.3	.003	T	88.5	.002	T	85.7	.007	T	95.8
Chrysothamnus puberulus	T	.001	+200.0	T	T	+100.0	--	T		T	.001	+500.0
Odostemon repens	.001	.002	+100.0	--	T		.001	.001	0.0	.003	.002	33.3
Purshia tridentata	.017	.011	35.3	.035	.005	85.7	.037	.003	91.8	.024	.001	95.8
Misc. Shrubs	.001	T	0.0	.001	.001	0.0	T	T	75.0	.002	.001	50.0
Total Shrubs	.130	.057	56.2	.132	.011	91.7	.147	.005	96.6	.152	.005	96.7

Note: For brevity all species with average density less than .001 are recorded as a trace (T). Percentage of loss is obtained from the actual figures.

The 1934 forage value of range represented by the three burned series was only 25 percent, 27 percent and 30 percent respectively of the 1932 value for light, moderate and heavy burns. Since the 1934 forage value of the unburned series was only 27 percent of 1932, it is evident that burning had little effect on grazing capacity. However, removal of the troublesome sagebrush by burning made considerably more forage available.

Data presented in table 1 are averages of densities for the total number of plots in each series. With the exception of sagebrush, no plant species occurred on every plot. Thickspike wheatgrass next to sagebrush occurred with greatest frequency.

In order to check the apparent reaction of vegetative classes and individual species to different intensities of burn the decrease or increase from the 1932 density was computed for each individual plot on which the species or class occurred. The true means of these values based on frequency of occurrence were then computed together with standard errors of the means. These figures were converted to percent in order to provide a common basis of comparison. Density values for total plant cover, grasses and shrubs as classes and four individuals (wheatgrass, needlegrasses, bluegrasses and sagebrush) were analyzed. Other grass, weed and shrub species were of too erratic occurrence to be treated statistically. Weeds as a class showed no significant change from the original 1932 densities on burned plots and were eliminated from this analysis. Mean percent decreases in density with standard errors are presented in table 2.

Table 2. Mean percent decrease of 1934 densities from densities obtained in 1932 before treatment with standard errors of means. The number of paired observations constituting the sample and the significance of differences are also included.

	Method of treatment (1933)			
	Unburned	Lightly Burned	Moderately Burned	Heavily Burned
All vegetation	65.1 ± 3.0	78.5 ± 4.5 1/	80.9 ± 3.7 2/	81.8 ± 3.9 3/
Frequency	117	43	72	68
All grasses	77.0 ± 4.5	74.2 ± 5.8	72.5 ± 5.8	70.2 ± 6.0
Frequency	117	43	72	68
Agropyron dasystachyum	83.0 ± 8.7	71.2 ± 10.3	65.0 ± 8.6	62.3 ± 7.2
Frequency	111	42	71	68
Stipas (grouped)	63.6 ± 10.7	75.0 ± 13.9	75.7 ± 14.2	75.0 ± 15.3
Frequency	82	35	63	43
Poas (grouped)	95.8 ± 8.2	85.7 ± 13.0	87.5 ± 9.8	87.0 ± 12.0
Frequency	82	39	62	53
All shrubs	56.2 ± 3.9	91.7 ± 7.3 4/	96.6 ± 5.0 5/	95.4 ± 5.1 6/
Frequency	117	43	72	68
Artemisia tridentata	60.9 ± 4.2	94.6 ± 7.1 7/	99.1 ± 5.8 8/	100.0 ± 4.8 9/
Frequency	117	43	72	68

		Differences between means with standard errors
1/	Significantly greater decrease in density than the unburned series	(13.4 ± 5.4)
2/	do	(15.8 ± 4.7)
3/	do	(16.7 ± 4.9)
4/	do	(35.5 ± 8.3)
5/	do	(40.4 ± 6.4)
6/	do	(40.5 ± 6.4)
7/	do	(33.7 ± 8.2)
8/	do	(38.2 ± 7.1)
9/	do	(39.1 ± 6.4)

When analyzed statistically intensity of burn failed to show any significant effect on the density of any species or class. However, the density of all vegetation, of all shrubs and of sagebrush was significantly less on the three burned series than on unburned plots. Wheatgrass density, which was apparently increased by burning in direct ratio to intensity of burn was not significantly greater than on unburned plots, but approached significance in the heavily burned series, the difference between means being 20.7 and the standard error of the difference ±11.3. Changes in density between burned and unburned treatments for total grasses, bluegrasses and needlegrasses were not statistically significant.

From a statistical standpoint, therefore, it appears that no measurable difference exists between intensities of burn. Moreover, with the exception of a reduction in total density which is obviously due to the destruction of shrubs, especially sagebrush, by fire there is no significant difference between densities of plant cover on burned and unburned range. The undesirable sagebrush virtually has been eliminated by fire while grasses, the most important forage, have not been damaged. The trend of grasses as a class and of wheatgrass as a species at least indicates that release from sagebrush more than counterbalances any possible detrimental effects from burning.

Table 3. Changes in total grass basal area and in total number of grass plants on quadrats according to different methods of treatment

	Total Basal Area (sq.cm.)		Total number of plants		Increase or decrease in 1934 (percent)		Av. Basal area per plant (sq. cm.)	
	1932	1934	1932	1934	Area	Number	1932	1934
Unburned Series								
Agropyron dasystachyum	1741	1554	1280	2205	-10.7	+72.3	1.4	0.7
Koeleria cristata	1866	1856	709	965	-0.5	+36.1	2.6	1.9
Poas (grouped)	765	880	268	399	+15.0	+48.9	2.9	2.2
Stipas (grouped)	2684	2550	443	516	-5.0	+16.5	6.1	5.9
Misc. grasses	1763	2134	1859	2036	+21.0	-4.6	0.9	1.0
Total	8819	8974	4559	6121	+ 1.8	+34.3	1.9	1.5
Lightly Burned Series								
Agropyron dasystachyum	2100	2066	1567	2922	- 1.6	+86.5	1.3	0.7
Koeleria cristata	1285	1490	651	587	-15.7	- 7.0	2.0	2.5
Poas (grouped)	342	436	152	267	+27.5	+75.7	2.2	1.6
Stipas (grouped)	3343	2863	482	487	-14.4	+ 1.0	6.9	5.9
Misc. grasses	1386	1567	890	2155	+13.1	+142.1	1.6	0.7
Total	8456	8422	3722	5528	- 0.4	+ 48.5	2.3	1.5
Moderately Burned Series								
Agropyron dasystachyum	1000	1624	651	1540	+62.4	+136.6	1.5	1.1
Koeleria cristata	1308	1715	474	578	+23.7	- 20.3	2.8	4.5
Poas (grouped)	346	475	81	144	+37.3	+ 77.8	4.3	3.3
Stipas (grouped)	1476	1476	315	289	0.0	- 8.3	4.7	5.1
Misc. grasses	397	253	559	239	-36.3	- 57.2	0.7	1.1
Total	4527	5543	2080	2590	+22.4	+ 24.5	2.2	2.1
Heavily Burned Series								
Agropyron dasystachyum	1499	1923	907	1502	+28.3	+ 65.6	1.7	1.3
Koeleria cristata	727	672	201	174	- 7.6	-13.4	3.6	3.9
Poas (grouped)	538	513	102	108	- 4.6	+ 5.9	5.3	4.8
Stipas (grouped)	1950	1816	166	126	- 8.4	-24.1	17.5	14.4
Misc. grasses	416	569	440	567	+36.8	+ 28.9	0.9	1.0
Total	5130	5493	1816	2477	+ 7.1	+ 36.4	2.8	2.2

Effect of different methods of treatment on the basal area and on the total number of grass plants was studied by comparing data from 1932 and 1934 chartings of the 58 meter-square quadrats. A summary of these data is presented in table 3. Results of analysis by Fisher's t method, Fisher (5), of the effects of treatment on basal area and on number of individual grass plants produced, including grasses as a class and certain individual species or genera are summarized in tables 4 and 5. Only species or genera which occurred on ten or more quadrats within a series were analyzed statistically with the exception of needlegrasses which were present on but seven heavily burned quadrats.

As shown in table 3, the basal area of grasses as a class remained practically unchanged from the 1932 figure in the unburned, lightly burned and heavily burned series, but increased 22 percent on moderately burned quadrats. Numbers of grass plants showed a considerable increase for every treatment. Percent increase was least on the moderately burned series due to a marked decrease in number of junegrass and miscellaneous grass individuals.

Wheatgrass showed slight decreases in basal area on unburned and lightly burned quadrats, but increased 28 percent on the heavily burned and 62 percent on the moderately burned series. The number of wheatgrass plants increased two-thirds or more for all treatments, more than doubling the 1932 frequency on the moderately burned series. Junegrass, showed area losses up to 14 percent on all treatments except the moderate burn where an increase of 24 percent was apparent. This species showed decreases of from 7 to 20 percent in number of individual plants on burned

Table 4. Significance of changes in grass basal area on quadrats as the result of different methods of treatment. 1934 data compared with 1932.

Species	TREATMENT: Unburned (check)			Lightly Burned			Moderately Burned			Heavily Burned		
	Number of Plots	Mean Change in area (sq.cm.)	Significance (Fisher's t)	Number of Plots	Mean Change in area (sq. cm.)	Significance (Fisher's t)	Number of Plots	Mean Change in area (sq.cm.)	Significance (Fisher's t)	Number of Plots	Mean Change in area (sq.cm.)	Significance (Fisher's t)
All grasses	20	+7.75	+0.33	15	-2.27	-0.10	12	+84.67	+2.99*	11	+33.00	+0.57
Agropyron dasystachyum	20	-9.35	-1.09	15	-2.27	-0.13	12	+52.00	+3.27**	11	+38.55	+1.91
Koeleria cristata	18	-0.56	-0.05	14	+14.64	+1.00	12	+33.92	+2.48*	10	- 5.50	-0.33
Poas (grouped)	16	+7.19	+0.89	14	+6.71	+0.93	11	+11.73	+1.07	11	- 2.27	-0.39
Stipas (grouped)	16	-8.38	-0.81	12	-40.00	-1.27	10	0.00	00	7	-19.1	-0.23

* Significant
** Very significant

Table 5. Significance of changes in number of grass plants on quadrats as the result of different methods of treatment. 1934 data compared with 1932.

Species	TREATMENT: Unburned (check)			Lightly Burned			Moderately Burned			Heavily Burned		
	Number of plots	Mean change in Number	Significance (Fisher's t)	Number of Plots	Mean change in Number	Significance (Fisher's t)	Number of Plots	Mean Change in Number	Significance (Fisher's t)	Number of Plots	Mean Change in Number	Significance (Fisher's t)
All grasses	20	+78.10	+5.78**	15	+120.40	+5.63**	12	+42.50	+0.96	11	+60.09	+3.43**
Agropyron dasystachyum	20	+46.25	+4.92**	15	+90.33	+4.24**	12	+74.08	+3.39**	11	+54.09	+4.37**
Koeleria cristata	18	+14.2	+2.05	14	-3.1	-0.59	12	-8.0	-0.89	10	-2.7	-0.40
Poas (grouped)	16	+ 8.2	+1.78	14	+8.2	+2.70*	11	+5.7	+2.71*	11	+0.5	+0.35
Stipas (grouped)	16	+ 4.6	+0.32	12	+0.4	+ .008	10	2.6	-0.70	7	-5.7	-1.47

* Significant
** Very significant

range, but an increase of 36 percent on unburned quadrats. Bluegrasses, comparatively unimportant either in basal area or number of plants increased their area in amounts up to 37 percent on all treatments except the heavy burn where a small decrease was evident. This genera increased in numbers on all treatments ranging from 76 percent and 78 percent on the light and moderate burn to 49 percent and 6 percent on the unburned and heavily burned quadrats. Needlegrasses decreased slightly on all treatments except the moderate burn where the 1932 and 1934 basal areas were exactly the same. The number of individuals of this genera varied directly as the intensity of burn, from an increase of 16 percent on unburned quadrats to a decrease of 24 percent on those heavily burned. Miscellaneous grasses including sedges, Idaho fescue and other minor species were erratic in behavior, increasing in area on all treatments except moderate burn where a decrease of 36 percent was noted, and increasing in number on all except the unburned and moderately burned series.

Statistical analysis (table 4) indicates that only on the moderately burned series were basal areas increased significantly. Furthermore, the barely significant increase of total grass basal area on this series chiefly was brought about by a very significant increase in the area of wheatgrass plus a smaller increase in junegrass. Variation in basal area response of these species to treatment other than moderate burning was so great between individual quadrats or the mean differences between 1932 and 1934 measurements were so small as to make the results statistically insignificant. The two genera, bluegrasses and needlegrasses, failed to show a significant change for any treatment.

Similar analysis of changes in total number of grass plants (table 5) shows a very significant increase for all treatments except the moderate burn. These increases principally were due to the very significant increase in numbers of wheatgrass plants for all treatments aided by a measurable increase in bluegrasses in the lightly burned series. On the moderately burned quadrats, however, combined increase of 137 percent in wheatgrass and 78 percent in bluegrasses, failed to produce a significant increase in total numbers of grasses. In the moderately burned series erratic behavior of minor species, especially sedge which showed a mortality of 420 individuals on one quadrat aided in preventing the 24 percent increase in numbers of total grass plants to be statistically significant. Elimination of this quadrat from the analysis, however, failed to change the situation materially. With the exception of wheatgrass and bluegrasses, other species or genera failed to show significant changes in numbers for any treatment.

The general increase in numbers of wheatgrass plants which largely accounted for any real increase in the total number of grass plants and which, except on the moderately burned series, resulted in no measurable change in basal area indicates either wholesale mortality or decrease in basal area of old established plants plus the establishment of new plants with smaller average basal area. Since this species is produced from rootstocks, the dispersion of large clumps into several smaller ones, is of remote possibility. Study of individual quadrat charts reveals that new wheatgrass plants with areas averaging approximately 1/2 square

centimeter were established subsequent to 1932. Many plants which in 1932 had areas of from 1 to 6 square centimeters showed decreased areas in 1934 on the lightly burned and unburned series, whereas on the moderate and heavy burn these larger tufts tended to maintain their 1932 areas and in many cases to increase them. This tendency to increase in basal area, however, was erratic on the heavily burned quadrats. In all treatments there was apparently mortality of the less vigorous individuals due to the effects of drought, fire or both.

Junegrass which increased measurably in basal area on the moderately burned quadrats without increasing in numbers shows, upon study of the 1932 and 1934 quadrat charts, a tendency for small plants mapped as groups in 1932 to have coalesced into single clumps in 1934. Numerous bluegrass plants, especially Sandberg bluegrass (Poa secunda), apparently became established subsequent to the 1932 charting. Basal area lost by older plants due to drought, however, was sufficient to prevent any significant increase.

The fact that basal area of grasses was measurably increased on burns of moderate intensity and did not decrease significantly on light or heavy burns, implies that controlled burning is not detrimental to this class of vegetation. Since the basal area of grasses protected both from grazing and from fire during the 3-year period remained unchanged, the increase on moderately burned quadrats is outstanding.

Estimates of grass vigor and of the intensity of past wind erosion were made on all quadrats at the time of charting in 1934. Wind erosion on burned areas occurred largely in the late summer and fall of 1933 subsequent to burning. This erosion was effectively arrested following establishment of plant cover in 1934. Estimates of plant vigor were segregated into six classes and coded as follows: (1) poor, (2) poor to fair, (3) fair, (4) fair to good, (5) good, and (6) excellent. Similarly, estimates of wind erosion were coded as: (1) no erosion, (2) slight, (3) slight to moderate, (4) moderate, (5) moderate to heavy, and (6) heavy. Means of estimates for the different series were as follows: (1) unburned; plant vigor 3.2, erosion 2.2; (2) lightly burned; plant vigor 3.5, erosion 3.0; (3) moderately burned; plant vigor 4.2, erosion 3.2; and (4) heavily burned; plant vigor 4.5, erosion 4.6. The fact that plant vigor apparently increased in direct proportion to intensity of burn is noteworthy. That erosion reached serious proportions only on the heavily burned quadrats, is also worthy of attention.

Amount of wind erosion was also estimated on 222 estimation plots concurrently with obtaining 1934 plant density estimates. Results, coded as above show erosion on 70 unburned plots to be 1.0, while on 36 lightly burned, 54 moderately burned and 62 heavily burned plots, the mean of estimates was 2.2, 2.9 and 4.3 respectively. While estimates of erosion on these larger plots were lower for unburned range and for burns of light and moderate intensity than were similar estimates on meter-square

quadrats it is interesting to note that estimates on heavily burned range were almost identical. It is evident that the amount of wind erosion varies in direct ratio to burning intensity, considerably increasing in rate on heavily burned range.

Effects of different burning intensities on maximum and average leaf length of thickspike wheatgrass and the two principal species of needlegrass, needle-and-thread (Stipa comata) and columbia needlegrass (S. columbiana), are summarized in table 6. All measurements were made in 1934. Plants were selected at random. Measurements of plants burned in 1932 were compared with means of all measurements on unburned plants. Plants burned in 1933, however, were compared directly with measurements of a like number of plants on adjacent but unburned range. No fewer than 25 plants were measured, ranging upward to 300.

Maximum and average leaf lengths were found to be significantly less on burned range for the three species. In no instance were standard errors of differences more than half the mean decrease. Thickspike wheatgrass showed the least decrease in either average or maximum length. Relative decrease in leaf length for this species appeared to lessen as the intensity of burn increased. Moreover, judging from comparable measurements on range moderately burned in 1932 and 1933, wheatgrass leaves tend to increase noticeably in length two years after burning. The two needlegrasses, however, showed no distinct tendency to recover either in maximum or average leaf length, nor was there apparent any striking difference in effects of the three intensities of burn except that leaves of plants on heavy burns tended to be relatively longer

Table 6. Comparative leaf lengths of grasses on adjacent unburned and burned range. (All measurements made in 1934.)

Species	Year of Burn	Intensity of Burn	Mean Lengths (inches) With Standard Errors of Mean: Unburned	Mean Lengths (inches) With Standard Errors of Mean: Burned	Dif. Between means with Standard Errors of Dif.	Decrease in Leaf Length on burned Plants (percent)
Average Length						
Agropyron dasystachyum	1932	Light	6.0 ± .0650*	4.8 ± .5367	1.2 ± .5406	20.0
	1932	Mod.	6.0 ± .0650*	5.0 ± .1281	1.0 ± .1435	16.7
	1933	Mod.	6.4 ± .0860	4.2 ± .0714	2.2 ± .1273	34.4
	1933	Heavy	5.8 ± .0663	4.3 ± .1049	1.5 ± .1241	25.9
Stipa comata	1932	Light	4.7 ± .0596*	3.2 ± .0600	1.5 ± .0848	31.9
	1932	Mod.	4.7 ± .0596*	3.0 ± .0787	1.7 ± .0990	36.2
	1933	Mod.	5.1 ± .1057	3.1 ± .0687	2.0 ± .1261	39.2
	1933	Heavy	4.0 ± .0813	2.6 ± .0700	1.4 ± .1072	35.0
Stipa	1932	Light	6.2 ± .0705*	4.2 ± .0490	2.0 ± .0860	32.3
	1932	Mod.	6.2 ± .0705*	4.1 ± .1855	2.1 ± .1985	33.9
	1933	Mod.	6.8 ± .1334	4.2 ± .0608	2.6 ± .1466	38.2
	1933	Heavy	5.6 ± .1005	3.7 ± .1381	1.9 ± .1709	33.9
Maximum Length						
Agropyron dasystachyum	1932	Light	7.5 ± .0832*	6.1 ± .1371	1.4 ± .1603	18.7
	1932	Mod.	7.5 ± .0832*	7.0 ± .1980	0.5 ± .2147	6.7
	1933	Mod.	7.7 ± .1308	5.5 ± .1158	2.2 ± .1442	28.6
	1933	Heavy	7.3 ± .1908	6.1 ± .1489	1.2 ± .2419	16.4
Stipa comata	1932	Light	8.0 ± .1168*	5.5 ± .2814	2.5 ± .3046	31.2
	1932	Mod.	8.0 ± .1168*	4.8 ± .0990	3.2 ± .1530	40.0
	1933	Mod.	8.5 ± .2184	5.0 ± .0788	3.5 ± .2324	41.2
	1933	Heavy	7.0 ± .1459	4.3 ± .1157	2.7 ± .1863	38.6
Stipa columbiana	1932	Light	10.5 ± .1252*	6.8 ± .2771	4.7 ± .3041	44.8
	1932	Mod.	10.5 ± .1252*	7.6 ± .3493	2.9 ± .3711	27.6
	1933	Mod.	11.2 ± .2427	7.2 ± .1225	4.0 ± .2721	35.7
	1933	Heavy	9.4 ± .2356	6.6 ± .1775	2.8 ± .2950	29.8

* Data for leaf lengths to compare with measurements on grasses burned in 1932 obtained by averaging all unburned leaf measurements.

than on moderately burned plants. Effect of burning upon flower stalk production was not pronounced for any species although in general, a higher percentage of plants on burned range produced flower stalks and averaged more stalks per plant than on unburned range.

The number of shoots per wheatgrass plant were counted on 250 randomly selected plants, 50 each being located on range burned lightly in 1932, moderately in 1932 and moderately in 1933, and 100 on range burned heavily in 1933. For each of these groups, similar counts were made for a like number of wheatgrass plants on adjacent unburned range. The mean number of stems per plant was found to be significantly higher on the burned range, differences between means being in all instances more than three times the standard errors of the difference. Comparing unburned range with range burned in 1932 there were 107 percent more shoots per plant on burns of light intensity and 79 percent more on range moderately burned. Similar comparisons of unburned range with range burned in 1933 showed 65 percent more shoots per plant on moderately burned range and 67 percent more on range burned heavily. No significant difference in the amount of increase between burn classes or between 1932 and 1933 burns was apparent.

Effects of burning on shrubs were studied in detail on the 29 browse plots burned in 1933. Sagebrush and bitterbrush composed more than 95 percent of the total crown spread in these plots in 1932. A summary of the reaction of these two species to light, moderate and heavy intensities of burn is presented in table 7.

Table 7. Effect of treatment on sagebrush and bitterbrush. (Data from browse plots; only mean values per plot are shown.)

	Unburned			Lightly Burned			Moderately Burned			Heavily Burned		
	1932	1934	% change	1932	1934	% change	1932	1934	% change	1932	1934	% change
Crown spread (sq. ft.)												
Sagebrush	21.8	22.5	+3.2	21.0	0.1	-99.5	18.5	0.0	-100.0	25.7	0.0	-100.0
Bitterbrush	5.9	7.5	+27.1	10.7	0.6*	-94.4	6.2	1.2*	-80.6	11.4	0.4*	-96.5
Average Height (feet)												
Sagebrush	1.46	1.37	-6.2	1.24	1.90	+34.7	1.34	0.0	-100.0	1.59	0.0	-100.0
Bitterbrush	1.06	0.81	-23.6	1.52	.49	-68.4	1.31	0.65	-50.4	1.46	.52	-64.4
No. seedlings												
Sagebrush	128.0	7.0	-94.5	104.2	0.0	-100.0	68.0	0.2	-99.7	44.2	0.2	-99.5
Bitterbrush	6.0	0.0	-100.0	6.7	0.0	-100.0	6.0	0.0	-100.0	3.3	0.1	-97.0
No. sprouts												
Sagebrush	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Bitterbrush	0.0	0.0		0.0	0.8		0.0	0.8		0.0	0.8	

* Crown spread of shoots sprouting from roots of parent plants subsequent to burning.

With the exception of the lightly burned series, where a small survival occurred, sagebrush was completely exterminated by fire. No evidence of sprouting back from the roots was found. Seedlings were reduced to only a fraction of a percent of the number present in 1932. The aerial portion of bitterbrush plants was completely destroyed by burning and bitterbrush seedlings, except for a small survival on heavy burns, showed 100 percent mortality. However, the burned bitterbrush plants sprouted back from the roots on the average of 0.8 of a plant per hundred square feet for each intensity of burn. The crown spread of these new shoots averaged 5.6 percent, 19.4 percent and 3.5 percent of the 1932 bitterbrush crown spread on lightly, moderately and heavily burned browse plots. This faculty of bitterbrush to sprout from the roots after the crown is killed by fire may prove highly important in the rehabilatory process. Given satisfactory protection from grazing, release from severe competition with sagebrush may afford this highly valuable browse species an opportunity to greatly increase on the burned over range.

Minor species, principally rabbitbrush, Oregon grape and snowberry sprouted or invaded after the burn. The combined crown spread of these species, however, was less than 1/2 square foot per plot, the average being .27, .46 and .13 square foot respectively on lightly burned, moderately burned and heavily burned plots.

Supplementing data obtained on the browse plots, counts were made of shrub survival at various locations throughout the area. On random lines run through burned territory, all sagebrush and bitterbrush plants

encountered were tallied as to whether dead or sprouting. Results from these counts show that on moderately burned range the mortality of sagebrush was 100 percent, while 25 percent of burned bitterbrush plants were sprouting. On heavy burns all sagebrush was dead while 19 percent of bitterbrush was sprouting. Numerous individuals of rabbitbrush, Oregon grape, snowberry, prickly gilia, snowbrush (Ceanothus velutinus) rose, and chokecherry (Prunus spp.) were found sprouting although exact counts were not made.

Fineleafed sagebrush, a species closely related to sagebrush and of such rare occurrence on unburned range that its presence was overlooked when the plant inventory was taken in 1932, was observed to be sprouting profusely in small isolated patches on burned range.

Effects of burning on certain soil properties were determined by analyzing soil samples collected at 48 randomly distributed stations in 1932, one year before the area was burned, and comparing these with similar analyses of samples collected at the same stations in 1934, one year following treatment. Mechanical composition of the soil, which approximated 66 percent sand, 21 percent silt and 13 percent clay, was unaffected by any treatment. Data on water-holding capacity were discarded since determinations of moisture equivalent describe essentially the same property and are obtained by more refined laboratory methods. With these exceptions, data obtained from laboratory analyses are summarized in tables 8 and 9. Since differences for any property of paired 1932 and 1934 soil samples were small, significance of differences was tested by Students'

"Z" method, Student (16), as modified by Love and Brunson (11) (12). In view of the small number of samples, differences giving odds below 100 to 1 were considered insignificant.

Differences between 1932 and 1934 data on unburned range, representing effect of climate alone, afford a satisfactory check to the three series designed to measure effects of different intensities of burning. As shown in tables 8 and 9 no significant change occurred in the unburned series for either soil layer. With this assurance that climate during the three years had no measurable effect on the soil, any variation noted within the separate burned series may be interpreted as principally due to the effect of burning.

No significant changes were noted in the top half inch of soil on lightly and moderately burned areas (table 8). On the heavily burned series, however, decreases of 24.79 percent and 24.22 percent respectively in organic matter and total nitrogen gave odds of 4,999 to 1 and 192 to 1 that the reduced values were not due to chance but were a real result of the treatment. Apparently, heat generated by light and moderate burns was not sufficient to affect these two properties. Organic matter considered in these analyses consisted of material incorporated in the soil mass distinct from litter and debris on the surface. Decrease in total nitrogen doubtless is closely related to decreases in organic matter. While not significant, a tendency for the upper layer of burned soils to increase in pH was apparent, a logical reaction when the concentration of basic minerals in the form of plant ash on the surface of burned soils is considered.

Table 8. Effects of different intensities of burning on the pH, organic matter, total nitrogen and moisture equivalent of the top half inch of soil. (Data from paired samples collected at definitely located stations one year before and one year after treatment.)

Treatment	No. of Paired Samples	Year	pH	Organic matter (percent)	Nitrogen (percent)	Moisture Equivalent (% of dry wt.)
Unburned (check)	17	1932	6.86	4.118	0.2023	17.69
		1934	6.87	4.829	0.2229	17.81
Percent change 1932-1934			+0.09	+17.27	+10.18	0.68
Odds secured by student's "Z"			0.0	1.1	12.6	0.0
Lightly Burned	8	1932	6.81	5.549	0.2570	18.14
		1934	6.88	5.370	0.2461	19.16
Percent change 1932-1934			+0.92	-3.23	-4.24	+0.11
Odds secured by student's "Z"			9.9	2.5	1.8	13.7
Moderately Burned	7	1932	6.86	5.233	0.2457	17.73
		1934	6.89	5.149	0.2423	18.03
Percent change 1932-1934			+0.42	-1.60	-1.38	+1.69
Odds secured by student's "Z"			2.9	0.0	0.0	1.6
Heavily Burned	16	1932	6.81	5.106	0.2258	16.88
		1934	6.88	3.840	0.1711	15.52
Percent change 1932-1934			+1.01	-24.79	-24.22	-8.06
Odds secured by student's "Z"			65.2	4,999.0	192.2	14.3
Mean Differences Between Burn Classes						
Light and Moderate			-0.50	+1.63	+2.86	+1.58
S.D. of difference			±0.82	±13.78	±17.15	±19.37
Light and Heavy			+0.09	-21.56	-19.98	-8.17
S.D. of difference			±0.66	±10.89	±13.51	±8.24
Moderate and Heavy			+0.59	-23.19	-22.84	-9.75
S.D. of difference			±0.75	±13.75	±15.47	±18.37

With the exception of a decrease of 11.20 percent in organic matter in the heavily burned series which gave odds of 152 to 1 that the reduction was not due to chance, no significant changes were apparent from 1932 values of samples collected from the lower soil layer (table 9). Decrease in total nitrogen approached significance in the same series. No tendency to increase in pH was apparent.

With the exception that reaction of pH of the lower soil layer to burning was apparently different on the moderately burned series than on light or heavy burns, no significant differences were found between the different burned series for either soil layer. However, since the mean decrease of pH in the moderately burned lower soil layer was so small and the reaction at individual stations so erratic (odds for "Z" = 0) it is doubtful that any real difference in pH exists between the other intensities of burn.

While not shown in the tables, the decrease of organic matter and nitrogen in the top soil of the heavily burned series represents a highly significant variation from the reaction of these properties on the unburned check plots, thus confirming the results secured by Students' "Z". The mean differences with standard errors were -34.4 $\pm$ 13.7 for organic matter and -16.1 $\pm$ 6.4 for nitrogen. The lower soil layer of the burned series showed no significant change from the unburned soils except that pH decreased on the moderately burned soils while increasing somewhat on the unburned. This variation apparently significant since the difference between means is more than twice the standard error of the difference (-1.58 $\pm$ .68) is probably not real since odds for "Z" were not above 4:1 in either case, implying considerable inconsistency in reaction for both treatments.

SUMMARY AND CONCLUSIONS

An area of spring-fall range on the Snake River plains in eastern Idaho was burned over in 1933 to determine the immediate effect of controlled burning on soil and vegetation in the absence of grazing.

In 1932 the approximate vegetative composition of the area was 45 percent grasses, principally thickspike wheatgrass and needlegrasses, 10 percent weeds, 40 percent sagebrush, and 5 percent miscellaneous shrubs, chiefly bitterbrush.

Normal precipitation on the area is considered to be higher than average for the Snake River plains due to proximity to the Snake River mountains.

Soil on the area differs from typical Snake River plains soil in that considerable fine sand is present in the top layer.

Vegetation showed a marked response to climate. Seasonal precipitation, probably the chief climatic factor, was 67 percent less in 1934 than in 1932. As a result of this drought, plant densities decreased 65.1 percent. Grasses, the most valuable forage, decreased 72 percent in density, weeds decreased 52 percent, while the current growth of shrubs was less than half of the 1932 production. These density decreases were responsible for a decrease of 72.8 percent in grazing capacity.

Basal area, the most stable portion of grasses, was not measurably changed on the unburned quadrats. Numbers of individual plants, however, increased very significantly for grasses as a class and for thickspike wheatgrass as a species.

Crown spread or potential foliage-producing area of sagebrush and bitterbrush increased on unburned plots. Average heights for these shrub species were greatly reduced due to curtailment in current growth and flower stalk production. Bitterbrush seedlings evidenced complete mortality in 1934 and but relatively few sagebrush seedlings persisted.

Climate during the 3-year period produced no measurable change in soil properties.

Wind erosion on unburned range was negligible.

Density of plant cover decreased on burned range. Significant decreases in individual species, however, were limited to sagebrush which was virtually exterminated by burns of light and moderate intensity and which completely disappeared on heavily burned areas.

Burning showed a tendency to increase grass density, especially thickspike wheatgrass, in direct proportion to intensity of bum, although statistically there was no measurable difference between grass density on burned and unburned range. Idaho fescue and sedges apparently were injured by burning. Needlegrasses showed less density on burned than on unburned plots but the difference was not statistically significant. There was no measurable difference between the effects of different intensities of burn on densities of any species or class.

Basal area of grasses increased significantly on burns of moderate intensity. Thickspike wheatgrass and junegrass increased measurably on this type of burn while needlegrasses and bluegrasses were unchanged.

Numbers of individual grass plants increased significantly on light and heavy burns but remained unchanged on the moderate burn. Thickspike wheatgrass increased significantly for all burn intensities. Bluegrasses increased in number on light and moderate burns. Other species showed no significant change. Erratic behavior of miscellaneous species, especially sedges, nullified the increased numbers of wheatgrass and bluegrass individuals on moderate burns.

Grass vigor varied directly from an index of 3.2 on unburned range to one of 4.5 on heavy burns.

Length of leaves was significantly less on burned range for thickspike wheatgrass, needle-and-thread grass, and Columbia needlegrass. In general a higher percentage of plants of these grasses produced flower stalks on burned range and average more stalks per plant. Thickspike wheatgrass on burned range produced from two thirds more to double the number of shoots than on unburned range.

Sagebrush failed to sprout after crowns were burned by fires of even light intensity. Bitterbrush showed crown mortality equal to sagebrush, but sprouted from the roots and recovered 5.6, 19.4 and 3.5 percent of its 1932 crown spread after burns of light, moderate and heavy intensity. On moderate and heavy burns, 25 percent, and 19 percent of the parent bitterbrush plants were found sprouting. All other shrubs showed ability to sprout after aerial portions were consumed by fire. Both sagebrush and bitterbrush seedlings had practically 100 percent mortality.

Forage value was not greatly changed on the burned range averaging 75, 73, and 70 percent less than 1932 on light, moderate and heavy burns, whereas drought alone caused a 73-percent decrease.

Burns of heavy intensity caused significant decreases in the amount of organic matter and the amount of total nitrogen in the top half-inch layer of soil. In the 2½-inch layer immediately below, a decrease in the amount of organic matter was apparently the only effect of heavy burning. Light and moderate burns showed no effect on soil properties.

Wind erosion occurring immediately subsequent to burning and largely arrested upon reestablishment of the plant cover, increased directly with intensity of burn.

From the foregoing it is concluded that under conditions similar to the experiment, controlled burning of spring-fall range with fires of light or moderate intensity will effectively remove sagebrush without apparent detriment to the soil or to the remainder of the vegetation.

Since no similar research has been conducted on other sagebrush ranges in the Intermountain region, it is not known if results from this study have wide application. Further research is needed to determine the effect of controlled burning on sagebrush ranges in other localities and also to determine the effect of regulated grazing on the soil and vegetation of burned ranges.

Table 9. Effects of different intensities of burning on the pH, organic matter, total nitrogen and moisture equivalent of the soil layer from 1/2 to 3 inches below the soil surface. (Data from paired samples collected at definitely located stations one year before and one year after treatment.)

Treatment	No. of paired Samples	Year	pH	Organic matter (percent)	Nitrogen (percent)	Moisture equivalent (% of dry wt.)
Unburned (check)	17	1932	6.88	3.182	0.1624	16.48
		1934	6.97	3.108	0.1578	16.16
Percent change 1932-1934			+1.37	-2.33	-2.83	-1.94
Odds secured by student's "Z"			3.9	2.8	3.0	58.1
Lightly Burned	8	1932	6.82	3.619	0.1836	17.15
		1934	6.94	3.592	0.1851	17.84
Percent change 1932-1934			+1.65	-0.75	+0.82	+4.02
Odds secured by student's "Z"			2.6	0.0	0.0	0.0
Moderately Burned	7	1932	6.93	3.467	0.1721	16.50
		1934	6.91	3.447	0.1821	16.71
Percent change 1932-1934			-0.21	-0.58	+5.82	+1.27
Odds secured by student's "Z"			0.0	0.0	6.5	20.7
Heavily Burned	16	1932	6.86	3.211	0.1598	15.98
		1934	6.94	2.852	0.1488	15.12
Percent change 1932-1934			+1.19	-11.20	-6.88	-5.38
Odds secured by Student's "Z"			3.0	152.0	73.5	44.6
Mean Differences Between Burn Classes						
Light and Moderate			-1.86	+0.17	-5.00	-2.75
S.D. of difference			±.763	±10.61	±7.72	±7.85
Light and Heavy			-0.46	-10.45	-7.70	-9.40
S.D. of difference			±.621	±9.52	±7.75	±6.12
Moderate and Heavy			-1.40	-10.62	-12.70	-6.65
S.D. of difference			±.689	±9.72	±7.11	±5.94

For a detailed discussion of results from 1932 to 1934 reference should be made to the manuscript "Effect of Controlled Burning On"., etc.

Results here summarized and discussed are those between 1934 to 1935 and 1935 to 1936.

Effect of Burning on Plant Density

Following the removal of the sagebrush, total density on burned areas changed in response to the changes in Agropyron dasystachyum. (Table 1). In 1935, contrary to the increase apparent to the eye, grass densities decreased. Since A. dasystachyum growth habit is rootstock it is very hard to estimate and different individuals will have widely different concepts of the amount required to make up a square foot of density. It is this personal error that is responsible for the sharp drop in the density of A. dasystachyum in 1935 and resultant decreases in "all grasses" and "total densities". This sharp drop in 1935 was followed in 1936 by a rise to 47 percent of 1932 densities with A. dasystachyum. Other grass species exhibited different trends. Festuca idahoensis maintained itself on the unburned areas in 1935 and 1936 but on the burned area after 1935 completely disappeared from the inventory. Poa spp. increased steadily on unburned areas but increased remarkably in 1935 on the burned area and then decreased even more drastically to even a lower level than it went to in 1934. On the burned areas Stipa spp. has continued at the same level.

Fremont Count Burning Project

Table 1

SUMMARY OF VEGETATIVE CHANGES-TRANSECT PLOTS

		Unburned					Burned 2/				
		1932	1934	1935	1936	Avail.	1932	1934	1935	1936	Avail.
Total Density	Dens.	.2810.	.0980.	.1192.	.1262.	52	.3029.	.0589.	.0523.	.0667.	93
	% 1/	100	35	42	45		100	19	17	22	
Agropyron dasytachyum	Dens.	.0445.	.0080.	.0038.	.0064.		.0609.	.0209.	.0168.	.0284.	
	%	100	18	9	14		100	34	28	47	
Festuca idahoensis	Dens.	.0090.	.0030.	.0022.	.0026.		.0011.	.0001.	.0001.	-	
	%	100	33	24	29		100	9	9	0	
Poa spp.	Dens.	.0170.	.0010.	.0020.	.0024.		.0189.	.0024.	.0046.	.0016.	
	%	100	6	12	14		100	13	24	8	
Stipa spp.	Dens.	.0310.	.0110.	.0069.	.0076.		.0439.	.0107.	.0106.	.0111.	
	%	100	35	22	25		100	24	24	25	
Total grasses	Dens.	.1259.	.0294.	.0199.	.0256.		.1407.	.0391.	.0348.	.0446.	
	%	100	23	16	20		100	28	25	25	
Total weeds	Dens.	.0254.	.0120.	.0129.	.0102.		.0169.	.0132.	.0092.	.0119.	
	%	100	47	51	40		100	78	54	70	
Artemisia tridentata	Dens.	.1100.	.0425.	.0669.	.0687.		.1070.	.0013.	.0020.	.0017.	
	%	100	39	61	62		100	1	2	2	
Purshia tridentata	Dens.	.0167.	.0112.	.0169.	.0201.		.0317.	.0027.	.0035.	.0059.	
	%	100	67	101	120		100	9	11	19	
Total shrubs	Dens.	.1297.	.0569.	.0864.	.0904.		.1453.	.0066.	.0083.	.0102.	
	%	100	44	67	70		100	5	6	7	

1/ Percentage compiled using 1932 density as 100 percent.

2/ Burned densities compiled as a weighted figure including light, medium and heavy burns.

When examined by burn class the place of A. dasystachyum in determining the reaction of all vegetation is even more apparent. Under light burns tripling its unburned density, advancing to six times on the medium and four times on the heavy burns it determines to a large degree the reaction of all vegetation. In contrast the density of Poa spp. and Festuca idahoensis decreases with the increase in intensity of burn. Stipa spp. increases on light and medium burns but decreases on the heavy burns to even a lower density than on the unburned areas.

"All weeds", similar to Stipa spp. increased on medium and light burns but decrease on heavy burns.

Volume Production

During the 1936 field season all transect plots were estimated using the weight estimate method in conjunction with estimates of availability.

If nothing else were accomplished by burning than removal of the sagebrush cover and grass cover remained the same the herbage available would have been increased 30 percent in the light, 41 percent in the medium and 45 percent in the heavy burns (table 3). But it is evident that the increase in grass and weed herbage has offset the loss due to the removal of sagebrush. When compared to data on density (table 2) the difference may be reconciled due to the facts that Agropyron dasystachyum is heavier per square foot density than is Artemisia tridentata the species that it replaced. Thus, in terms of total

Table 2.

Comparison of density of vegetation by burn classes.

	Unburned	Burned		
		Light	Medium	Heavy
Total density	12.617	7.039	7.719	5.512
Agropyron dasystachyum	.637	2.068	3.457	2.695
Poa spp.	.241	.205	.178	.118
Festuca idahoensis	.259	.011	.003	.004
Stipa spp.	.756	1.177	1.466	.687
All grasses	2.558	3.873	5.476	3.787
All weeds	1.018	1.344	1.366	.893
Artemisia tridentata	6.868	.600	.065	.007
Purshia tridentata	2.007	1.055	.654	.225
All shrubs	9.041	1.822	.877	.632.

Density expressed in square feet per 100 square feet ground surface.

Table 3.

Comparison of productivity of burn classes-all herbage

	Unburned	Burned		
		Light	Medium	Heavy
Average availability	52	82	93	97
Total weight herbage	1487	1261	1407	1014
Total available weight	773	1034	1309	984
Agropyron dasystachyum	188	497	724	583
Poa spp.	33	31	21	16
Festuca idahoensis	21	1	0	0
Stipa spp.	108	165	190	91
All grasses	414	741	985	726
Total available grasses	215	608	916	705
All weeds	82	258	297	175
Artemisia tridentata	776	102	7	1
Purshia tridentata	192	129	87	38
All shrubs	991	262	126	113

Productivity expressed in pounds per acre.
Availability expressed as percent of the total forage that is available to sheep.

available weight the increases have been 34 percent for the light, 69 percent for the medium and 28 percent for the medium burn. Examination of this change by species shows that grass production increasing from 75 to 125 percent is responsible for changes in total production. Individual species of grasses betray different reactions. Poa spp. and Festuca idahoensis as in the density data decreases inversely to the intensity of burn. Stipa spp. increase approximately 60 to 90 percent in the light and medium burns but decrease in the heavy burn. It is then the doubling or tripling of the A. dasystachyum production that is responsible for the reaction of the group of all grasses. "All weed" production has doubled or tripled in all burn classes. The "all shrub" production forming approximately 70 percent of the unburned production decreases directly with the increase in intensity of burn until it forms but 11 percent of the total production on the heavy burn. Artemisia tridentata for whose removal the area was burned has nearly entirely disappeared on the medium and heavy burns. Purshia tridentata, a valuable shrub for forage, sprouts from the roots and has succeeded in a production of 66 percent of that of the original stand on light burns and a little less than 45 percent on medium burns with a heavier decrease on heavy burns.

The trend of palatable herbage (table 4) is slightly different than that of all herbage principally because the increase following burning was by a low palatability species, Agropyron dasystachyum. Despite this, available forage has doubled on light and heavy burns and tripled on the medium burns.

Table 4.

Comparison of productivity of burn classes - palatable herbage.

	Unburned	Burned		
		Light	Medium	Heavy
Average availability	52	82	93	97
Total weight forage	326	474	559	358
Total available weight	170	389	520	347
Agropyron dasystachyum	47	124	181	145
Festuca idahoensis	13	1	0	0
Poa spp.	19	23	16	12
Stipa spp.	91	125	141	65
Palatable grass herbage	211	313	376	249
Total available palatable grass herbage	108	257	350	242
Palatable weed herbage	29	109	149	90
Artemisia tridentata	16	2	0	0
Purshia tridentata	67	45	31	13
Palatable shrub herbage	86	52	34	18

Productivity expressed in pounds per acre
Availability expressed as percent of the total forage that is available to sheep

Using a feed requirement per ewe with suckling lamb of 12 pounds of palatable forage per day a section of unburned range would support 1,000 ewes for 7 days under management. As a result of burning, using the average production of all burn classes, the carrying capacity has been increased to 18 days.

Therefore, from the standpoint of removal of sagebrush and the increase in herbage from an increase in availability and in response to the liberation of soil moisture by the removal of sagebrush, burning has in this area been a marked success. However, it must be remembered that the success attained was on an area having a heavy understory of grass under the original stand and where no grazing use was made of the area for a year following the burn.

Basal Area

As expressed by basal area the effect of burning on grasses is as varied as that indicated by density but not in all cases following the same trend (table 5 and figure 1).

In 1935 Agropyron dasystachyum increased slightly over the 1934 area, Koeleria cristata decreased sharply in all burn classes, Poa spp. increased markedly, Stipa columbiana changed but slightly, Stipa comata decreased in all burn classes with the result that "all grasses" increased in the medium and heavy burns and decreased slightly on light burns.

Grass Basal Area Changes by Burn Class Expressed as Percent of Original Area

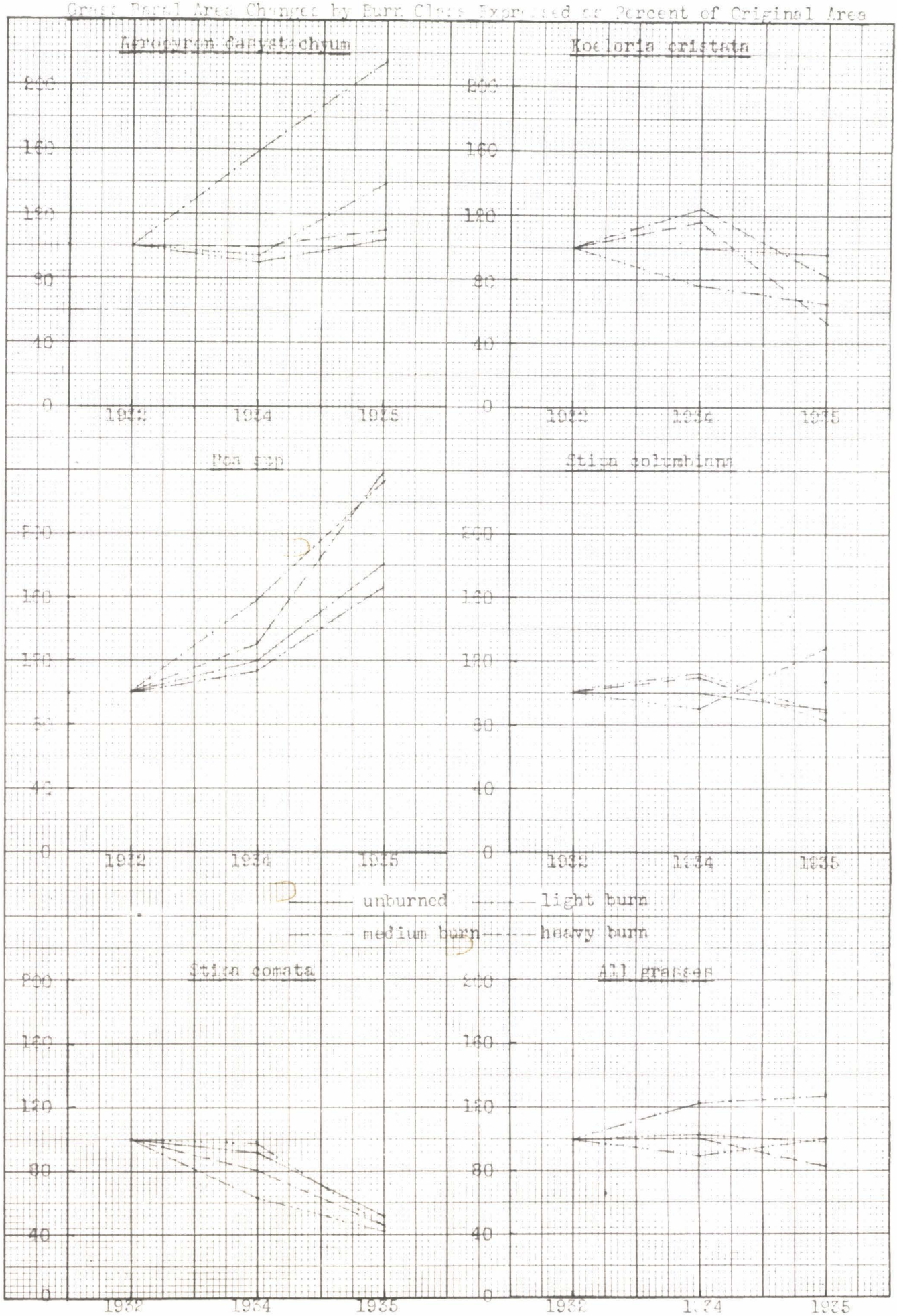


Table 5

SUMMARY OF BASAL AREA CHANGES - QUADRATS

		Unburned			Light Burn			Medium Burn			Heavy Burn		
		1932	1934	1935	1932	1934	1935	1932	1934	1935	1932	1934	1935
	No.	64.0			104.5			54.2			82.5		
	Area	87.1			140.3			83.4			136.3		
	No.		110.2			194.8			125.0			100.8	
Agropyron dasystachyum	Area		77.7 89			137.7 98			132.1 158			129.2 95	
	No.			146.4			238.9			224.8			208.0
	Area			91.8 105			150.9 108			179.0 215			186.7 137
	No.	35.4			42.1			39.5			18.3		
	Area	93.3			85.7			109.0			66.1		
	No.		48.2			39.1			30.8			13.8	
Koeleria cristata	Area		92.7 99			99.5 116			135.1 124			50.9 77	
	No.			61.9			39.0			53.4			17.8
	Area			87.5 94			45.6 532			89.5 82			43.2 65
	No.	13.4			10.1			6.8			9.3		
	Area	38.3			22.8			28.8			48.9		
	No.		22.0			13.4			15.5			29.1	
Poa spp.	Area		45.8 120			29.1 128			45.6 158			55.6 114	
	No.			51.3			34.0			28.3			33.7
	Area			69.1 180			54.5 239			66.8 232			81.4 166
	No.	8.8			14.1			12.2			5.1		
	Area	41.2			40.3			58.2			28.4		
	No.		14.6			19.3			11.1			4.1	
Stipa columbiana	Area		40.8 99			45.8 109			53.2 91			30.4 107	
	No.			19.9			23.6			27.2			6.8
	Area			37.0 90			33.3 83			67.9 117			25.1 88
	No.	13.3			17.7			12.4			9.0		
	Area	93.1			181.8			62.0			145 .3		
	No.		11.2			12.7			11.8			8.7	
Stipa comata	Area		86.6 93			146.0 80			60.8 98			91.4 63	
	No.			11.7			18.5			5.4			8.4
	Area			47.8 51			83.6 46			28.4 46			61.9 43
	No.	228.0			248.1			173.0			165.1		
	Area	440.9			563.7			377.2			466.4		
	No.		306.0			369.0			243.3			212.2	
Total grasses	Area		448.7 102			561.1 100			465.2 123			421.0 90	
	No.			425.0			453.7			403.7			350.9
	Area			430.6 98			469.4 83			478.1 127			463.1 100

These trends differ only in Agropyron dasystachyum from those indicated by density. In 1935 density decreased markedly as contrasted to the increases in basal area. It is reasonable to believe that this difference is due entirely to a change in the concept of density with the species and not to a real difference. This is corroborated by a comparison of photographs for the two years (see photograph album) (Burning Projects).

Soil Moisture and Plant Development

In 1935 five pairs of hurdle enclosures were established on the Fremont County burn to determine the differences if any between the soil moisture and plant development on burned and unburned areas. Each individual of the pair was located adjacent to the other, one being in the burn and the other in the unburned area. Each area was a rod square enclosed in wire netting to protect against sheep grazing.

Within each plot 5 plants of each of the following species were located and staked; Agropyron dasystachyum, Stipa spp., Poa secunda, and Koeleria cristata. Staked plants were measured and observed at weekly intervals from April 20 to August 8 according to the "Instructions for Plant Development Observations." Around the outside of each enclosure soil samples were secured at weekly intervals. One 100-gram sample was secured from each plot of the 0- to 6-, 6- to 12-, and 12- to 18-inch layers.

Soil Moisture

From the time of the very first sample on April 20 until the last of July, soil moisture on the unburned area was consistently higher than that on the burned area. This difference amounted to approximately 3 percent in the 0- to 6-inch layer, 2 percent in the 6- to 12-inch layer and in the 12- to 18-inch layer a variable amount from 1 to 7 percent.

This decrease in available water may be explained in the results from analyses of soil samples collected prior to and after burning. As is shown in the manuscript, water holding capacity was decreased ____ percent by burning. It may be that moisture percolated on through the soil saturating it to capacity and since that was percent less the difference during the season remained the same. Evidently demands for moisture were the same from the vegetation on the two areas which would indicate that grasses and weeds had increased as much as the moisture liberated by the removal of the sagebrush allowed.

Plant development and growth

The character of the year did not allow observations as to the time that plant species started growth. Fall rains in 1934 initiated regrowth and this remained green under the snow all winter. When it was possible to get out to the area in the spring approximately 5 centimeters of growth already existed.

Total leaf growth on burned and unburned areas in A. dasystachyum, P. secunda and K. cristata is definitely greater on unburned areas. In Stipa spp. the opposite trend is shown. Greater height growth on unburned areas is the reverse of expected trends. Since the moisture formerly used by A. tridentata was liberated it was expected that greater height growth would be attained on burned areas. However, this increase was manifested rather in an increase in the number of stems or leaves per plant as shown in the manuscript on burning.

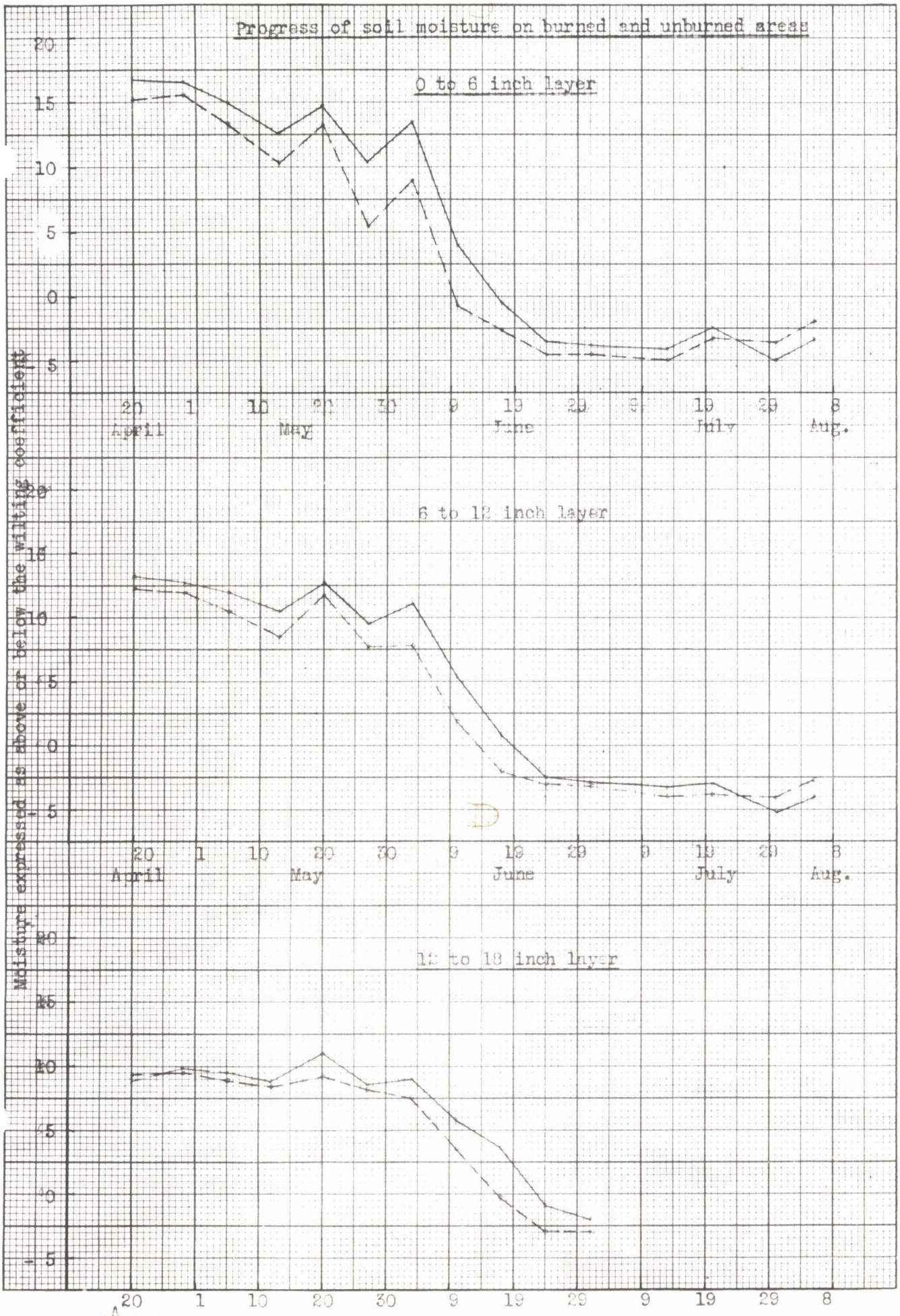
In average and maximum height of flower stalks the superiority of height on unburned areas is divided; P. secunda and K. cristata flower stalks are taller on unburned areas, Stipa spp. and A. dasystachyum are taller on burned areas.

Flower stalk numbers are consistently and definitely greater on the burned areas for all species.

The progress of development is in general more rapid for A. dasystachyum on the burned areas. Flower stalks appeared 4 days earlier, heads were fully out only 1 day sooner. These differences, however, are only indications in other species, no definite reaction seems to be visible.

Conclusions

About the only two distinct results of burning with regard to plant development is the decreased leaf height, increased flower stalk height and increased flower stalk numbers on burned areas.


Progress of soil moisture on burned and unburned areas
0 to 6 inch layer
6 to 12 inch layer
12 to 18 inch layer
Moisture expressed as above or below the wilting coefficient
20
15
10
5
0
5
20 April
1
10
20
30
May
9
19
29
June
9
19
29
July
8
Aug.

March of soil moisture is apparently unaffected by burning except to lower the entire seasonal moisture content in all layers approximately 2 or 3 percent.

Table 6. Plant development and growth on burned and unburned areas - Fremont County Project

	Agropyron dasystachyum			Stipa spp.			Poa secunda			Koeleria cristata		
	Burn	Unburn	Diff.	Burn	Unburn	Diff.	Burn	Unburn	Diff.	Burn	Unburn	Diff.
Average leaf height	11.96	16.20	4.24	18.80	16.96	-1.84	6.08	8.16	2.08	9.24	10.76	1.52
Max. leaf height	15.84	22.20	6.36	28.32	24.72	-3.60	8.30	11.16	2.86	13.36	15.60	2.24
Average Fl. St. Ht.	49.64	41.92	-7.72	72.76	65.38	-7.38	37.24	45.00	7.76	34.52	38.54	4.02
Max. Fl. St. Ht.	52.74	42.50	-10.24	92.16	80.56	-11.60	43.48	50.00	6.52	38.04	43.84	5.80
No. flower stalks	3.64	.65	-2.99	36.28	14.88	-21.40	22.56	5.92	-16.64	14.64	8.24	-6.40
Date fl. st. appear	5/25	5/29	4	5/22	5/23	1	5/6	5/5	-1	5/18	5/18	-
Date heads show	6/15	6/18	3	6/13	6/11	-2	5/23	5/23	-	6/4	6/4	-
Date heads fully out	6/23	6/24	1	6/23	6/23	-	6/1	5/31	-1	6/11	6/11	-
Seed being diss.	8/8	8/7	-1	7/7	7/10	3	7/8	7/10	2	7/21	7/23	2
Seed disseminated				7/22	7/25	3	8/6	8/11	5	8/2	8/3	1
Plant drying	6/14	6/18	4	6/16	6/17	1	5/31	6/9	9	6/9	6/14	5

Burning on Spring-Fall Range in Southeastern Idaho and Subsequent Grazing Management Practices.

Grazing practices immediately following the removal by fire of sagebrush from wheatgrass-sagebrush ranges determine the type of vegetation cover that will establish itself. Results from the Fremont County burning project[1/] showed that burning did not decrease forage production the first season after burning, but rather through eradication of big sagebrush that from 60 to nearly 100 percent more forage was made available to livestock.

1/ George Stewart, G. D. Pickford and J. F. Pechanec. Effect of Controlled Burning on Spring-Fall Range in Southeastern Idaho. November 19, 1936. (In the process of being published, Forest Service, Washington, D. C.)

Observations on many burned areas point to the necessity of grazing management after burning. Some observations have suggested that early and continous grazing after a fire does serious injury to that range. A careful study in the field suggests that areas both burned and grazed produce only about 25 percent of the forage that exists under favorable controlled conditions. If proper grazing management after burning will aid in establishing a good grass cover and prevent sagebrush from re-establishing itself, it certainly deserves application. To investigate and determine, if possible, the proper grazing practices after burning, a set-up on the Fremont County Burning Project area was designed.

Location and Methods of Securing Data

The Fremont County Burning Project is located in the northeast upper part of the Sanke River plains area, about fifteen miles northeast of St. Anthony, Idaho. It is on the same area as and in connection with this project that these grazing management studies have been conducted.

One-acre enclosures were established in various sections of the area. These 1-acre enclosures were treated as follows:

1. Unburned and fenced for total protection, enclosures 1, 2 and 5. E-2 was only partly burned, the unburned portion only being used here.
2. Unburned and grazed, enclosures G-1 and G-2. Data from the unburned portions of transects 1, 2, 3, and 4 have also been used here.
3. Burned and fenced for total protection, enclosures 3 and 4 and the burned portion of enclosure 2.
4. Burned and grazed. No. 1-acre enclosures were established as the open range, burned and grazed plots of transects 1, 2, 3, and 4, provided this treatment.
5. No protection from grazing following burning; enclosure G-5. It was burned in early summer of 1934 and grazed beginning the fall of the same year.
6. One spring season's protection from grazing after burning, plots of transects 1, 2, 3, and 4 which were burned in the fall of 1933 and grazed beginning the fall of 1934.

7. One spring and one fall season's protection from grazing after burning, enclosure G-4 which was burned in the fall of 1935 and grazed beginning spring of 1935.

8. Two spring and one fall season's protection from grazing after burning, enclosure G-3. It was burned in the fall of 1932 and grazed beginning the fall of 1934.

In each of these 1-acre enclosures ten 100-square-foot circular plots upon which to estimate density and a number of meter square quadrats for basal area and number studies were established. All the plots and quadrats from which data have been taken are classified as Artemisia-grass type. Data have been analyzed as burned or unburned, not by the different intensities of burn.

Time of Burning

Burning began in 1932. Backfire strips were burned at critical points. Enclosures E-4 and G-3 were burned, but inclement weather prevented further burning that fall. In the summer of 1933, about 50 percent of the area was burned. Part of enclosure 2 was accidently burned during that season and enclosure 5 was established in 1934 to take the place of enclosure 2. Enclosures E-2 and G-4 were heavily burned in 1933. Enclosure G-5 was burned in 1934.

Time and Extent of Grazing

Grazing began in the fall of 1934. An inspection of that fall's grazing was made between November 10 and 24. Grazing on the whole area had by November 10 proceeded unsatifactorily; enclosure G-1 and G-2 were practically ungrazed, G-3 was 10-20 percent utilized, and G-4 was ungrazed. Inspections of spring and fall grazing for 1935 and 1936 were not made.

In all likelihood, none of the plots were grazed in accordance with the plans during the entire period. Even if grazed the enclosures were probably not used severely enough to be detrimental.

Presentation and Discussion of Data

Density estimates were made in 1932 previous to burning, and they were made again in 1934, 1935 and 1936. These density estimates for the different years and under the various treatments are presented in table 1. The figures are the average densities in square feet per 100-square-foot plots for all grasses, all weeds, all browse and total density. Significance of Fisher's "t" values see table of Significant Differences of Density Changes in appendix 1.

Density changes expressed in percent as calculated from the density figures in table 1 are presented in table 2.

Quadrats were mapped in 1932 previous to burning, and again in 1934 and 1935. The average basal area in square centimeters and number of plants per meter square quadrat for the different years and under the various treatments are presented in table 3. The table includes data of the major grasses-- Agropyron caesystachyum, Koeleria cristata, Stipa columbiana and Stipa comata, and all grasses, perennial weeds and annual and seedling weeds.

Basal area and numbers of plant changes in percent as calculated from table 3 are presented in table 4.

Table 1.- Average density in square feet per 100-square-foot plots and significances of changes from one year to the next year.

	1932	1934	Sg.	1935	Sg.	1936	Sg.		1932	1934	1935	Sg.	1936	Sg.
	Density	Density	diff	Density	diff	Density	diff		Density	Density	Density	diff	Density	diff
Treatment		**Unburned and protected**							**A- No protection after burning**					
All grass	9.77	3.09	3/-	1.56	3/-	2.58	3/+		13.75 Burned	1.75			3.64	3/+
All weeds	0.88	0.91	3/-	0.88	1/-	0.55	1/-		2.75 before	0.80			1.38	2/+
All browse	11.06	4.56	3/-	5.87	3/+	6.15	1/+		11.40 estimat-	0.25			0.58	1/+
Total density	21.71	8.56	3/-	8.31	1/-	9.28	2/+		27.90 ed.	2.80			5.60	3/+
Treatment		**Unburned and grazed**							**B- 1 spring season's prot. after burning**					
All grass	14.09	3.51	3/-	1.85	3/+	2.59	3/+		13.43	4.00	3.56	3/-	4.60	3/+
All weeds	1.83	0.90	1/-	1.01	1/+	0.86	3/-		1.64	1.29	0.94	3/-	1.14	3/+
All browse	12.85	5.59	3/-	7.93	3/+	7.77	1/-		13.92	0.75	0.96	3/+	1.10	1/+
Total density	28.77	10.00	3/-	10.79	3/+	11.05	2/+		28.99	6.04	5.46	3/-	6.84	3/+
Treatment		**Burned and protected**							**C- 1 sp. and 1 fa. seasons' prot. after burn.**					
All grass	14.76	5.29	3/-	3.89	3/-	4.82	3/+		10.90	3.85	3.00	3/-	4.29	3/+
All weeds	1.55	0.90	3/-	0.70	1/-	0.96	2/+		1.80	1.15	0.40	2/-	0.78	2/+
All browse	14.98	0.28	3/-	0.33	1/+	0.70	3/+		14.00	0.40	0.85	2/+	0.68	1/-
Total density	31.29	6.45	3/-	4.92	3/-	6.48	3/+		26.70	5.40	4.25	2/-	5.75	3/+
Treatment		**Burned and grazed**							**D- 2 sp. and 1 fa. seasons' prot. after burn.**					
All grass	13.43	4.00	3/-	3.56	3/-	4.60	3/+		23.95	7.35	4.05	3/-	4.68	1/+
All weeds	1.64	1.29	3/-	0.94	3/-	1.14	3/+		5.65	2.40	1.05	3/-	1.98	3/+
All browse	13.92	0.75	3/-	0.96	2/+	1.10	1/+		15.10	0.50	0.80	1/+	1.10	1/+
Total density	28.99	6.04	3/-	5.46	3/-	6.84	3/+		44.70	10.25	5.90	3/-	7.76	3/+

1/ Not significant. 2/ Significant. 3/ Highly significant. Sg. diff. = Significance of difference.

Table 2.- Density changes in percent

	1932 to 1934	1932 to 1935	1932 to 1936	1934 to 1935	1935 to 1936		1932 to 1934	1932 to 1935	1932 to 1936	1934 to 1935	1935 to 1936
Treatment	Unburned and protected						A- No protection after burning				
All grass	-68	-84	-74	-50	+65			-87	-74		+108
All weeds	+10	00	-38	-3	-48			-71	-50		+72
All browse	-59	-47	-44	+29	+5			-98	-94		+132
Total density	-61	-62	-57	-3	+12			-90	-80		+100
Treatment	Unburned and grazed						B- 1 spring season's prot. after burning				
All grass	-75	-87	-82	-47	+40		-70	-73	-66	-11	+29
All weeds	-51	-45	-53	+12	-15		-21	-43	-30	-27	+21
All browse	-56	-38	-40	+42	-2		-95	-93	-92	+28	+15
Total density	-65	-62	-62	+8	+2		-80	-81	-76	-10	+29
Treatment	Burned and protected						C- 1 sp. and 1 fa. seasons' prot. after burn.				
All grass	-64	-74	-67	-26	+24		-65	-72	-61	-22	+43
All weeds	-42	-55	-38	-22	+37		-36	-78	-57	-65	+95
All browse	-98	-98	-95	+18	+112		-97	-94	-51	+112	-20
Total density	-79	-84	-79	-24	+32		-80	-84	-78	-21	+35
Treatment	Burned and grazed						D- 2 sp. and 1 fa. seasons' prot. after burn.				
All grass	-70	-73	-66	-11	+29		-69	-83	-80	-45	+16
All weeds	-21	-43	-30	-27	+21		-58	-81	-65	-56	+89
All browse	-95	-93	-92	+28	+15		-97	-95	-93	+60	+120
Total density	-79	-81	-76	-10	+25		-77	-87	-83	-42	+32

Table 3.- Average basal area and numbers of plants per meter square quadrat.

Treatment	Year	Ada		Ker		Ste		Sco		All grass		Perennial weeds		An sd* weeds
		Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	No.
Unburned	1932	74.7	67	71.0	39	98.7	22	22.3	4	325.2	202	2.8	6	61
and	1934	62.2	88	55.0	42	105.8	41	25.7	3	319.8	282	8.5	15	122
protected	1935	59.7	106	74.8	46	98.7	49	24.7	3	408.8	366	11.0	20	89
Unburned	1932	97.0	66	98.8	36	15.4	2	79.0	8	435.5	228	13.8	28	105
and	1934	83.8	116	97.5	50	14.7	5	66.4	10	437.0	312	160.2	44	28
grazed	1935	98.3	149	85.7	59	18.6	10	53.7	9	437.9	432	182.0	63	93
Burned	1932	90.8	62	70.1	33	30.0	10	55.6	5	447.4	253	7.4	15	52
and	1934	140.4	146	58.6	20	37.7	12	57.1	4	485.3	289	265.9	35	9
protected	1935	190.0	243	55.6	29	33.9	18	36.2	8	505.0	439	231.2	29	123
Burned	1932	141.4	93	99.2	38	28.0	6	121.2	15	437.0	175	16.1	14	60
and	1934	150.7	159	112.0	31	24.7	5	133.8	11	486.1	244	58.4	23	14
grazed	1935	179.5	245	65.4	44	24.1	5	73.5	11	425.0	375	118.6	48	104
A- No protection	1932	16.5	15	101.0	38	73.5	40	344.0	68	662.8	235	20.0	38	66
after	1934	11.5	21	104.2	56	78.5	42	362.8	33	701.5	237	426.8	58	7
burning	1935	14.0	21	85.5	78	84.8	55	64.0	38	436.5	382	194.0	34	177
B- One spring	1932	141.4	93	99.2	38	28.0	6	121.2	15	437.0	175	16.1	14	60
season's protection	1934	150.7	159	112.0	31	24.7	5	133.8	11	486.1	244	58.4	23	14
after burning	1935	179.5	245	65.4	44	24.1	5	73.5	11	425.0	375	118.6	48	104
C- One spring and one	1932	43.5	38	34.0	10	145.5	25	317.5	24	585.5	106	6.5	13	129
fall seasons' protec-	1934	125.2	54	67.0	12	174.2	15	72.2	15	501.2	107	19.0	14	6
tion after burning	1935	102.0	127	65.0	17	136.8	26	67.5	13	434.8	198	36.2	17	167
D- Two spring and one	1932	107.0	87	102.8	37	108.8	36	316.0	36	771.2	289	19.5	39	68
fall seasons' protec-	1934	123.1	174	188.0	62	125.0	54	181.5	28	774.9	510	319.9	60	4
tion after burning	1935	112.8	172	53.0	46	89.8	60	110.5	33	579.2	545	236.2	10	35

*An = Annual; sd = seedling.

Table 4.- Changes in basal area and numbers of plants in percent*

Treatment	Year	Ada		Ker		Stc		Sco		All grass		Perennial weeds		Annual weeds
		Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	No.
Unburned	1932-34	-17	+32	-23	+8	+7	+86	+15	-23	-2	+40	+200	+171	+100
and	1932-35	-20	+58	+5	+19	00	+121	+10	-38	+26	+82	+288	+259	+48
protected	1934-35	-4	+20	+36	+10	-7	+19	-4	-20	+28	+30	+29	+33	-26
Unburned	1932-34	-14	+76	-1	+42	-5	+219	-16	+27	+1	+37	+1065	+57	-74
and	1932-35	+1	+127	-13	+66	-21	+567	-32	+4	+1	+90	+1223	+127	-11
grazed	1934-35	+17	+29	-12	+17	+27	+109	-19	-18	-1	+38	+14	+44	+237
Burned	1932-34	+55	+137	-16	-39	+26	+17	+3	-22	+8	+14	+3499	+139	-82
and	1932-35	+109	+295	-22	-13	+13	+77	-35	+52	+13	+74	+3029	+95	+136
protected	1934-35	+35	+67	-5	+41	-10	+51	-37	+94	+4	+52	-13	-18	+1235
Burned	1932-34	+7	+71	+13	-19	-12	-17	+10	-27	+11	+40	+262	+68	-77
and	1932-35	+27	+165	-34	+15	-14	-6	-39	-28	-3	+114	+635	+254	-73
grazed	1934-35	+19	+55	-42	+42	-2	+14	-45	-1	-13	+53	+103	+111	+645
A- No protection	1932-34	-30	+40	+3	+47	+7	+5	+5	-51	+6	+1	+2034	+53	-89
after	1932-35	-15	+40	-15	+105	+15	+38	-81	-44	-34	+63	+870	-11	+168
burning	1934-35	+22	00	-18	+39	+8	+31	-82	+15	-38	+61	-55	-41	+2429
B- One spring	1932-34	+7	+71	+13	-18	-12	-17	+10	-27	+11	+39	+263	+64	-77
Season's protection	1932-35	+27	+163	-34	+16	-14	-17	-39	-27	-3	+114	+637	+243	+73
after burning	1934-35	+19	+54	-42	+42	-2	00	-45	00	-13	+54	+104	+109	+643
C- One spring and one	1932-34	+188	+42	+97	+20	+20	-40	-77	-38	-14	+1	+192	+8	-95
fall seasons' protec-	1932-35	+134	+234	+91	$70	-6	+4	-79	-46	-25	+87	+457	+31	+29
tion after burning	1934-35	-19	+135	-3	+42	-21	+73	-7	-13	-13	+85	+91	+21	+2683
D- Two spring and one	1932-34	+15	+100	+83	+68	+15	+50	-43	-22	00	+76	+1541	+54	-94
fall seasons' protec-	1932-35	+5	+98	-48	+24	-17	+67	-65	-8	-25	+89	+1111	-75	-49
tion after burning	1934-35	-8	-1	-72	-26	-28	+11	-39	+18	-25	+7	-26	-83	+775

*Percents calculated from total basal area and numbers of plants.

Burned as Against Unburned Area Both Protected

Burning changed the vegetation in subsequent years, especially the percent composition of grasses, weeds, and browse of the total density. After burning, grasses came back to make up about two-thirds of the total density where as under unburned conditions the grasses made up about one-third or less of the total density. Due to climatic factors alone, grasses from 1932 to 1934 and to 1936 decreased 68 percent and 74 percent respectively while due to burning and climatic factors grasses between the same years decreased 64 percent and 67 percent respectively. Burning evidently stimulated the grasses. Weeds reacted very irregular; their response seemed to depend entirely on the moisture conditions which if favorable the weeds would grow under any treatment. The object of burning was to destroy the browse, especially the sagebrush which makes up nearly the entire browse cover; this was accomplished as indicated by the density figures in the years after burning.

The individual grasses reacted differently under the different treatments. From quadrat studies during the period from 1932 through 1935 under burned treatment, Agropyron dasytachyum increased 109 percent, Koeleria cristata decreased 22 percent, Stipa columbiana increased 13 percent, Stipa comata decreased 35 percent and all grasses increased 20 percent, Koeleria cristata increased 5 percent, Stipa columbiana did not change, Stipa comata increased 10 percent and all grasses increased 26 percent. The change in plant numbers was similar to the change in basal area. The weeds seemed to respond more favorably under burned conditions.

Unburned-Protected as Against Unburned-Grazed

As records on the actual degree of use of these areas were not taken, the following comparisons merely give the trends of the vegetation under the treatments.

From 1934 to 1935 grasses were still on the down hill trend due to previous drought conditions and they decreased slightly more under protection than under grazing; weeds decreased slightly, an insignificant amount, under protection and increased an insignificant amount under grazing; browse increased significantly under both but more under grazing; and total density decreased an insignificant amount under protection and increased 8 percent, a significant amount, under grazing. From 1935 to 1936 grasses increased 65 percent under protection and 40 percent under grazing; weeds decreased an insignificant amount under protection and 15 percent, a highly significant amount, under grazing; browse increased slightly under protection and decreased slightly under grazing, neither change being significant; and total density increased 12 percent under protection and only 2 percent under grazing, both increases being significant.

From the quadrat studies of 1934 and 1935 in basal area, under protection Agropyron dasystachyum decreased 4 percent, Koeleria cristata increased 36 percent, Stipa columbiana decreased 7 percent, Stipa comata decreased 4 percent and all grasses increased 28 percent; under grazing Agropyron dasystachyum increased 17 percent, Koeleria cristata decreased 12 percent, Stipa columbiana increased 27 percent, Stipa comata decreased 19 percent and all grasses decreased 1 percent. The number of plants did not change in all cases in the same direction as the change in basal area.

Burned-Protected as Against Burned-Grazed

There were only 23 density plots and 9 quadrats under protection whereas there were 183 density plots and 22 quadrats under grazing. The replication was somewhat small in the protected treatment but adequate in the grazed treatment.

From 1934 to 1935 in density grasses decreased 26 percent under protection and just 11 percent under grazing; weeds decreased an insignificant amount under protection and a highly significant amount under grazing; browse, which existed in only a small amount on this burned area, increased more under grazing; and total density decreased 24 percent under protection as against 10 percent under grazing. From 1935 to 1936 grasses increased 5 percent more under grazing than under protection, the increase in each case being highly significant; weeds increased more under protection than under grazing; the small amount of browse present increased considerably more under protection; and total density increased 7 percent more under protection, both increases being highly significant.

From quadrat studies from 1934 to 1935 in basal area, Agropyron dasystachyum increased 35 percent under protection and just 19 percent under grazing, Koeleria cristata decreased just 5 percent under protection and 42 percent under grazing, Stipa columbiana decreased 10 percent under protection and only 2 percent under grazing, Stipa comata decreased 37 percent under protection and 45 percent under grazing and all grasses increased 4 percent under protection and decreased 13 percent under grazing. The changes in number of plants were about the same under both treatments.

Protection Practices After Burning

Since grazing by these different protection practices did not begin the same year, the differences in vegetation between the various years of data do not all register the effects of grazing. The comparisons will be made between the vegetation present in 1932 previous to the burning and that present at the end of the 1936 field season in case of density plots and that at the end of 1935 in case of quadrats. The different periods of protection will be referred to by letters; A-no protection from grazing after burning, B-one spring season's protection from grazing after burning, C-One spring and one fall seasons' protection from grazing after burning, and D-two spring and one fall seasons' protection from grazing after burning.

In all cases grasses decreased in density, decreasing the least under C, secondly under B, thirdly under A, and most under D; weeds decreased the least under B, secondly under A, thirdly under C, and most under D; browse was present in such small amounts that the changes were not significant; and total density decreased least under B, secondly under C, thirdly under A, and most under D.

From quadrat data in basal area from 1932 through 1935 *Agropyron dasystachyum* increased 134 percent under C, 27 percent under B, and 15 percent under D and decreased 15 percent under A; *Koeleria cristata* increased 91 percent under C and decreased 15 percent under A, 34 percent under B, and decreased 6 percent under C, 14 percent under B, and 17 percent under D; *Stipa comata* decreased 39 percent under B, 65 percent under D, 79 percent under C, and 81 percent under A; all grasses

decreased just 3 percent under B, 25 percent under C and under D, and 34 percent under A; and weeds increased about equally well under D and A, thirdly under B, and last under C.

The following diagram shows in concise form the substance of the above paragraph:

Species	* 1	2	3	4
A. dasystachyum----	C	B	D	A
K. cristata -------	C	A	B	D
S. columbiana -----	A	C	B	D
S. comata ---------	B	D	C	A
All grass ---------	B	C-D	-	A
Weeds -------------	A-D	-	B	C

* Order of favorableness of protection period, 1 being the most favorable etc.

From this diagram it can be seen that B - one spring season's protection after burning and C - one spring and one fall seasons' protection after burning were the most favorable considering all the vegetation. Practices A and D gave about same results, A probably being better.

Summary

The grasses on the unburned area changed by the climatic factors alone decreased more than the grasses on the burned area changed by climatic factors plus burning. On the unburned area grass made up 2.58 square feet of density and browse made up 6.15 square feet of density of a total density of 9.28 square feet. On the burned area grass made up 4.82 square feet of density and browse made up 0.70 square feet of density of a total density of 6.48 square feet. Burning destroyed the unpalatable sagebrush to 90 percent or more and stimulated the palatable forage grasses, especially Agropyron dasystachyum, to increased density.

On the unburned range the vegetation did just about as well under the degree of use which it received as the vegetation which was protected from grazing. From 1934 to 1935 grasses, which were still showing ill effects of the 1934 drought, decreased slightly less under grazing than under protection; however, with the return of more favorable climatic conditions, the grasses increased more from 1935 to 1936 under protection than under grazing. Total density reacted very similar to the grasses. Of the major grasses Agropyron dasystachyum and Stipa columbiana increased under grazing whereas they decreased under protection; Koeleria cristata and Stipa comata reacted just the opposite, increasing under protection and decreasing under grazing.

On the burned range the vegetation did just as well under the grazing use that it received as under protection. Grasses from 1934 to 1935 decreased more under protection than under grazing. From 1935 to 1936 they increased slightly more under grazing than under protection.

Weeds and browse were in such small densities as to be unimportant. In other treatments Agropyron dasystachyum and Stipa columbiana responded to some unnatural stimulus; in the case of unburned and burned area it was the burning, and in the unburned protected and grazed it was the grazing. Upon bringing these two stimulating treatments together as a burned-grazed treatment, Agropyron dasytachyum was not so responsive, as it increased more under burned-protected than under burned-grazed; however, Stipa columbia reacted more favorably under burned-grazed than under burned-protected.

Under the various periods of protection from grazing after burning, grasses responded most favorably and about equally well under B - one spring season's protection and under C - one spring and one fall seasons' protection. No protection after burning caused grasses to decrease the greatest degree the year following burning while the longest period of protection was not anymore favorable than the shorter periods of protection.

Conclusions

Since 1-acre enclosures are small areas for grazing trials on a practical basis, since the replication of density plots and quadrats were inadequate, since no accurate records of the use of the range have been taken, and since this study covers only a 2-year period of grazing use, the following statements are made merely as the trends of the vegetations under the various treatments are made and not as conclusive facts.

On wheatgrass-sagebrush spring-fall range on which there is a good understory of grass, burning can be used to noteworthy advantage in removal of the sagebrush and establishment of an available grass cover.

Vegetation and especially grasses on unburned range protected from grazing will decrease tremendously under adverse climatic conditions. A moderate degree of use tends to stimulate the grasses in that they decrease less under grazing then under protection.

On burned range grasses tend to do better under some degree of grazing than under protection. Agropyron dasystachyum responds favorably to burning-protected treatment and to unburned-grazed treatment, but it does not respond so favorable under burning-grazed treatment. Burning and grazing separately seem to stimulate this grass but the two together seem to be too much of a stimulus.

Of the various protection periods from grazing after burning treated in this management study, one spring season's protection from grazing after burning and one spring and one fall seasons' protection from grazing after burned tend to be most favorable to the return and establishment of the vegetation. No protection immediately following the burn tends to work a hardship on the vegetation. A longer protection period than one spring season or one spring and one fall seasons is not any more favorable to the vegetation and it is not as economical. These statements are made as trends in the case and not as conclusive facts. Since records of grazing use were not taken, it cannot accurately be said that these areas were actually grazed or just exposed to grazing and if grazed the degree to which they were used.

The results obtained apply to spring-fall range on the Fremont County Burning Project. Similar results could only be expected from range land comparable in topography, soil type, seasonal precipitation, and vegetation cover to this Fremont County range land.

Recommendations

It is recommended that these management studies under the present set-up of enclosures be discontinued. This recommendation is made for the following reasons:

1. One-acre enclosures are exceedingly small on which to conduct grazing trial from a practical range standpoint.
2. Ten plots for density estimates and 2 to 4 quadrats for basal area and number of plants studies in each enclosure and two to three enclosures under each treatment does not five adequate replication for a statistically sound basis.
3. Records of actual grazing use have never been kept. It cannot be said that the areas were actually grazed or if just exposed to grazing. If the plots were grazed, in all probability they were not grazed intense enough to be registered by the change in vegetation.
4. The management of grazing for the year or so immediately following burning is the important point in the connection of management with burning. Since the management studies of the past two or so years have been at fault in many respects, to continue the studdes with the same set-up under revised and better methods will not correct the faults of the past. What has been done has had its effect on these areas and cannot be changed by fatther proper studies.

Appendix 1.- Significance of difference in density changes.

Treatment	1932-1934 Mean Density Change	1932-1934 Fisher's "t"	1932-1934 Fqy [4]	1934-1935 Mean Density Change	1934-1935 Fisher's "t"	1934-1935 Fqy [4]	1935-1936 Mean Density Change	1935-1936 Fisher's "t"	1935-1936 Fqy [4]
Unburned and protected									
All grass	-7.344	4.909 [3]	16	-2.071	5.493 [3]	23	+1.194	5.330 [3]	27
All weeds	-0.708	7.453 [3]	12	-0.154	0.360 [1]	13	-0.403	1.824 [1]	18
All browse	-7.059	9.630 [3]	17	+1.480	4.111 [3]	25	+0.194	0.632 [1]	27
Total density	-14.471	8.326 [3]	17	-0.239	0.495 [1]	23	+1.029	*2.774 [2]	26
Unburned and grazed									
All grass	-9.956	21.004 [3]	137	-1.345	9.539 [3]	132	+0.700	8.335 [3]	131
All weeds	-1.296	1.331 [1]	125	+0.150	1.756 [1]	107	-0.201	2.831 [3]	113
All browse	-7.296	21.333 [3]	137	+2.847	13.304 [3]	131	+0.218	0.826 [1]	131
Total density	-18.434	29.270 [3]	137	+1.617	6.243 [3]	133	+0.771	**2.511 [2]	130
Burned and protected									
All grass	-9.545	11.216 [3]	22	-1.386	7.036 [3]	22	+1.023	3.503 [3]	22
All weeds	-0.881	3.113 [3]	21	-0.275	1.554 [1]	20	+0.325	2.559 [2]	20
All browse	-16.205	14.055 [3]	22	+0.375	1.569 [1]	4	+0.429	4.086 [3]	7
Total density	-26.591	22.727 [3]	22	-1.568	5.851 [3]	22	+1.455	4.649 [3]	22
Burned and grazed									
All grass	-10.164	21.905 [3]	183	-0.437	5.202 [3]	183	+1.011	4.931 [3]	183
All weeds	-0.422	2.776 [3]	173	-0.547	5.758 [3]	138	+0.340	4.048 [3]	153
All browse	-13.858	31.784 [3]	183	+0.248	2.918 [3]	103	+0.335	1.024 [1]	120
Total density	-24.396	40.728 [3]	183	-0.664	5.627 [3]	183	+1.474	6.066 [3]	183

Treatment	1934-1935 Mean Density Change	1934-1935 Fisher's "t"	1934-1935 Fqy [4]	1935-1936 Mean Density Change	1935-1936 Fisher's "t"	1935-1936 Fqy [4]
A- No protection after burning						
	+1.900	6.810 [3]	10			
	+0.575	2.426 [2]	10			
	+0.650	2.063 [1]	5			
	+2.800	5.809 [3]	10			
B- 1 sp. season's protection after burning						
All grass	-0.437	5.202 [3]	183	+1.001	4.931 [3]	183
All weeds	-0.547	5.748 [3]	138	+0.340	4.048 [3]	153
All browse	+0.248	2.918 [3]	103	+0.335	1.024 [1]	120
Total density	-0.664	5.627 [3]	183	+1.474	6.066 [3]	183
C- 1 sp. and 1 fq. seasons' prot. after burning						
All grass	-0.850	4.009 [3]	10	+1.300	4.235 [3]	10
All weeds	-0.833	2.678 [2]	9	+0.417	2.743 [2]	9
All browse	+1.250	2.894 [2]	4	-0.250	0.776 [1]	7
Total density	-1.150	2.300 [2]	10	+1.500	3.916 [3]	10
D- 1 sp. and 1 fq. seasons' prot. after burning						
All grass	-3.300	15.421 [3]	10	+0.625	1.883 [1]	10
All weeds	-1.350	5.696 [3]	10	+1.028	3.879 [3]	9
All browse	+1.500	1.500 [1]	2	+1.000	2.618 [1]	3
Total density	-4.350	9.335 [3]	10	+1.850	5.226 [3]	10

1/ Not significant.
2/ Odds 19:1, significant.
3/ Odds 99:1, highly significant.
4/ Fqy = Frequency, number of plots on which vegetation appeared in measurable density.

* Lacks 0.026 of being highly significant.
** Lacks 0.110 of being highly significant.

Statistical Design of Fremont Management Study

In the preceding report analyzing the results from a study at the Fremont County Burning Project designed to determine proper grazing management following burning a definite series of results are presented indicative, as the author states, only of trends due to management. Reasons for this lack of reliance, incomplete records, failure of plots to receive prescribed treatments, inclusion of three different years burn and three different intensities of burn within plots of different treatments have been adequately discussed.

Assuming that each plot had been burned the same year to the same intensity and treated according to the plan results as portrayed by each plot might be real. Even then certain features of the design would need to be carefully considered before results could be accepted.

In order that a valid test of the significance of treatment differences may be made, certain definite pre-requisites of the design of the experiment must be fulfilled.

1. With a simple design in which each treatment has one plot devoted exclusively to its trial, replications of treatments plots must be made to provide degrees of freedom for error with which to test the significance of differences between treatments.
2. These treatment replications should be assigned at random, that is, each plot should have an equal chance of receiving any treatment.

Sampling units (transect plots) within plots do not provide this replication because each unit within a plot receives the same treatment and the difference between two plots receiving different treatments may be a combination of difference in location and treatment effect or either individual singly.

With the four one-acre plots, grazed plots 3, 4, 5, and 6, specifically set aside to study the proper management after burning, no replication was afforded with which to test significance. Thus the only possible test is to use variation within plots to test difference supposedly due to treatment between plots.

Using the data from E-4, G-3, 4 and 5 an analysis of variance is conducted to test treatment differences. (Table 1)

Since an F of 3.43 exceeds a probability of 95 to 5 that treatment differences are significantly different we are justified in picking out individual differences between treatments and testing them.

Any two treatment sums differing in excess of 200 acre significantly different. Thus as we would expect and had hoped G-4, receiving one spring and one falls' protection following burning is significantly better than G-5 no protection after burning. What we are unable to explain however is why total protection (G-5)and does differ from two spring and one falls' protection (G-3).

Table 1.- Significance of difference between treatments using all grass densities.

Area	Percent change from 1932 to 1936 by plot										
	1	2	3	4	5	6	7	8	9	10	Σ
C-5	84	80	69	78	60	65	65	72	75	70	718
E-4	50	60	33	71	80	58	36	72	60	58	578
C-4	68	42	75	58	74	81	72	67	27	62	476
C-3	78	82	80	83	78	84	78	73	84	78	798
Σ											2,570

Correction factor = $(2,570)^2/40$ or 165,122

$\Sigma(84)^2 + \ldots\ldots (78)^2 = 192,948 - 165,112 = 27,836$

$\frac{\Sigma(718)^2 + \ldots (798)^2}{10} = 171,299 - 165,112 = 6,187$

$27,836 - 6187 = 21,649$

Due to	D.F.	S.S.	M.S.	F.
Between areas	3	6,187	2,062.3	3.43
Within areas (error)	36	21,649	601.4	
Total	39	27,836		

Difference between two sums that will be significant to p = .05 is $\sqrt{601.4 \times 10 \times 2} = 109.67 \times 2.26 = 219.34$.

This analysis since it uses error within one-acre plots to test difference between one-acre plots presumes that the error between one-acre plots receiving the same treatment is the same as that within.

The fallacy of this assumption need hardly be tested because any investigator acquainted with soil heterogeniety and other variables would recognize that less variation occurs within one-acre plots than between plots located at widely spaced intervals.

To determine whether criticism may be justifiably applied to the Fremont County area, data from two one-acre plots treated alike, E-3 and E-4, are analyzed to determine if between plots is the same as the variation within. (Table 2).

Since an F of 6.99 exceeds a probability of 99 to 1 that the difference between two plots receiving the same treatment is greater than the variation within plots we are justified in asserting that the test made in Table 1 was not valid.

What difference does this actually make in practice? With two treatments, unburned-grazed and burned-ungrazed we have replication. Also as appears from Table 2 of the preceding report, these two treatments exhibit an average difference of 15 percent in the reaction of all grass density.

When this data is analyzed by variance in the accepted manner the difference between plots receiving the same treatment is again found to be significant when tested in terms of the variation within and treatment differences when tested in terms of the variation between plots treated alike are not significant and may be due to chance.

Table 2.- Significance of difference between plots receiving the same treatment.

E-3	50	75	81	71	68	79	85	73	76	69	727
E-4	50	60	33	71	80	58	36	72	60	58	578
											1,305

Correction = $(1,305)^2/20$ = 85,151

$\Sigma(50)^2 + \ldots..(58)^2$ = 89,121 - 85,151 = 3,970

$\frac{(727)^2 + (578)^2}{10}$ = 86,261 - 85,151 = 1,110

3970 - 1,110 = 2,860

Due to	D.F.	S.S.	M.S.	F.
Within plots	18	2,860	158.9	
Between plots	1	1,110	1,110	6.99
Total	19	3,970		

Significant F to P = .01 =

Conclusion

Even if all plots had been treated according to the original design no valid test of the significance of treatment effects can be made.

False conclusions may arise from assuming that variation within plots is a valid test for treatment effect.

Recommendations

Failure to provide a sound statistical design together with the other features inherent in the study of proper management following burning at the Fremont County Burning Project are sufficient cause for discontinuing this phase of the work. This should be done immediately because any results arising from a continuance of the work will require an expenditure of time and maoney not justified by the usability of results.

Table 3.- Significance of difference between treatments as tested by variation between plots of same treatment.

Area Treatment		Percent change from 1932 to 1936 by plots										Σ
		1	2	3	4	5	6	7	8	9	10	
G 1	UnG	86	93	93	83	68	82	83	67	63	77	795
G 2	UnG	25	87	83	78	73	81	80	79	83	84	753
E 3	B P	50	75	81	71	68	79	85	73	76	69	727
E 4	B P	50	60	33	71	80	58	36	72	60	58	578
												2,853

$\Sigma (86)^2 + \ldots (58)^2 = 209{,}001$

			Σ
UnG	795	753	1,548
B P	727	578	1,305
			2,853

Correction $(2{,}853)^2/40 = 203{,}490$

$\frac{(795)^2 + \ldots (578)^2}{10} = 206{,}165$

$\frac{(1{,}548)^2 + (1{,}305)^2}{20} = 204{,}966$

209,001 - 203,490 = 5,511

209,001 - 206,165 = 2,836
206,165 - 204,966 = 1,199
204,966 - 203,490 = 1,476

Due to	D.F.	S.S.	M.S.	F.
Within blocks (a)	35	2,836	81.0	-
Between blocks (b)	3	1,199	399.7	4.93*
Treatment	1	1,476	1476	3.69**
Total	39	5,511		

* Tested in terms of (a)
** Tested in terms of (b)